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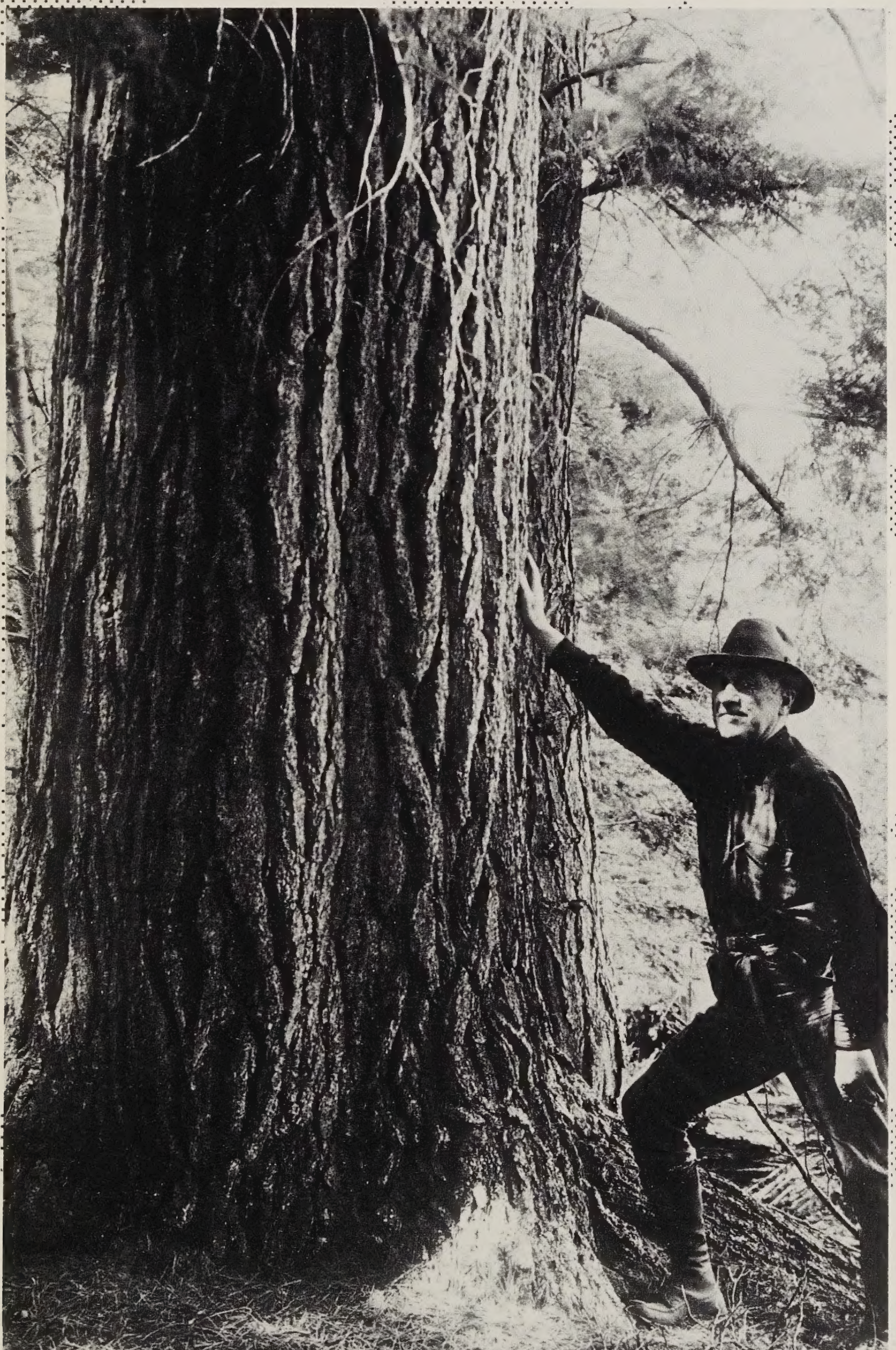
Impact of Forest Stressors on the Tree Species of the Nicolet National Forest – Past, Present and Future



About the Cover: This photo shows a White Pine on Butternut Lake, in the Nicolet National Forest.
Photo date: January 19, 1934

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Impact of Forest Stressors on the Tree Species of the Nicolet National Forest – Past, Present and Future

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USDA Forest Service
Northeastern Area State and Private Forestry
Forest Health Protection

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EXECUTIVE SUMMARY

This report is a record of disturbance agents that have affected the health of tree species on the Nicolet National Forest, especially over the past century. In addition, it provides information that can be used to predict how future management decisions and the disturbance regimes they bring about will affect the health of various tree species on the Forest. Not every future disturbance is predictable, but many are, and their possible effects on forest tree species can in many cases be described.

Tree Health on the Nicolet

The issue of the health of the forest is an important concept in the management of the Nicolet. Forest health can be viewed at a number of different scales ranging from individual trees to entire landscapes (see Chapter 1). Healthy trees are relatively easy to define, but defining a healthy forest landscape is much more difficult. The Nicolet National Forest can be viewed as a forest landscape. As such, it is very diverse, and evaluating its overall health is complex and far beyond the scope of this report. Therefore, we have chosen to evaluate and report on health at the level of individual trees or in some cases individual stands of trees. In this report, we do not consider dead or dying trees as healthy. We do this with the full understanding of the role that dead, dying, and decaying trees play in healthy forests. In that regard, disturbance agents that kill or weaken trees should not always be viewed as causing a forest health problem. Many of these agents are part of the natural cycle of forest communities and serve important roles in cycling nutrients and creating conditions for the regeneration of future forests.

This discussion is not meant to be all inclusive; rather, it is meant to generate further discussion. If we can identify and predict future outcomes using this historical record, then perhaps we can avoid many tree health problems in the future.

Past Land-Use

As discussed in Chapter 1, most of the forest currently found on the Nicolet originated in the early 1900's following a 50- to 70-year period of destructive land-use. The forests of the region have made a significant recovery from the abuse that occurred during the logging era of the middle to late 1800's and the brief agricultural era that followed. Despite the obvious recovery, these disturbances were intense and significantly altered the area. The legacy of that time period will continue to play an important role in the overall health of the forests of the Nicolet well into the next century, and it is very important that any discussion of future tree health on the Nicolet begin with an understanding of how current forest stands originated.

Disturbance Regimes

Disturbance is a part of any healthy functioning forest ecosystem (see Chapter 2). Historical evidence shows that areas of the Nicolet were blown down during wind storms and that occasional fires occurred. Undoubtedly, native insects and pathogens killed many single trees or entire stands of trees. These events served to recycle nutrients and provide favorable conditions for trees and plants that demand sunlight. Today, disturbance is just as important as it was previously, though the types of disturbances found on the Forest are different. Fire suppression now limits the size and extent of fires, and harvesting activities alter the species and age distribution of many forest stands. How, where, and when disturbances will be created will play an important role in the future forest composition of the Nicolet.

Forest Management Practices

Future management scenarios on the Nicolet could range from a hands-off policy to one stressing intensive forest management. Whatever scenario is stressed will affect the health of trees in some way. A hands-off policy that discourages human-caused disturbances will also discourage certain tree species such as aspen, paper birch, oak, and jack pine. On the other hand, it could encourage species such as sugar maple and American beech. The past history of disturbances, human-made and "natural," including insects and pathogen outbreaks, should provide a basis for predicting what is likely to happen to various tree species under different management scenarios.

Many management practices can directly affect the health or vigor of individual trees. A healthy, vigorous tree can better defend itself from insect or pathogen attack than can a weakened or stressed tree. Practices such as thinning can develop larger, healthier tree crowns that can increase tree vigor. In some cases, such as in oak stands, thinning to increase tree vigor may become very important in the maintenance of oak as a dominant species due to the presence of gypsy moth, an exotic leaf feeder of oaks. A management practice currently not in use, the application of herbicides, would improve the ability of land managers to establish some tree species, such as white and red pine. Judicious use of herbicides could improve the overall health and vigor of young pine by removing competing vegetation.

Finally, basing future forest management decisions on sound ecological principles could alleviate several of our major tree health concerns. The advent of ecological classification systems is a major step toward that goal. These systems provide the basis for managing tree species on ecologically appropriate sites, thus avoiding past mistakes that placed some tree species on sites that were too wet or too dry, too nutrient poor or too nutrient rich. These mistakes often led to tree health problems.

Introduction of Exotic Organisms

Perhaps the greatest threat to the future health of the tree species of northeast Wisconsin is from the introduction and establishment of exotic organisms (see Chapter 4). Past history includes well-documented cases where the introduction of an exotic organism disrupted forest ecosystems. In Wisconsin, Dutch elm disease killed millions of American elm trees. Today, large American elms are rare, and the lowland hardwood forest, which is well represented on the Nicolet, has been significantly altered by the loss of this once dominant tree. At present, more than 360 exotic insects and more than 20 exotic pathogens are known to attack woody plants in North America. Many of these are already well established on the Nicolet.

Gypsy moth, a major exotic forest defoliator, has become established in northeastern Wisconsin. Gypsy moth outbreaks are common in forests dominated by oak and aspen. Gypsy moth caterpillars also feed readily on basswood, tamarack, and willow and can feed upon white pine and hemlock. Gypsy moth feeding, which can have profound effects in some forests, will alter the ecology of the Nicolet, especially in areas dominated by oaks. Several exotic insects and pathogens that could eventually become a problem on the Nicolet are already present in the U.S. Any of these could have a severe impact on the Nicolet.

Forest Type Highlights

Discussion on the various forest types can be found in Chapter 3. Specific highlights within each of forest types found on the Forest include:

Northern Hardwood

The sugar maple resource that dominates this forest type appears to be in relatively good health, though some concern over the "quality" of sugar maple trees has been expressed. Both yellow birch and hemlock are apparently experiencing regeneration problems that could reduce stand diversity in

the northern hardwood type. Deer have been implicated, but other contributing factors appear to be involved. Butternut is plagued by butternut canker, and there is a very real possibility of losing butternut as a tree species on the Forest. Basswood has suffered defoliation on several occasions over the past 15 years by introduced basswood thrips. Further, basswood now faces a new threat in gypsy moth. These two exotic insects, could cause reduced growth or localized mortality in basswood.

Pine

Most jack pine stands on the Forest are relatively old, having originated in the 1930's. Increased mortality and top-kill should be expected in these stands, since jack pine stands rapidly deteriorate after age 50 to 60 years. In fact, several of these stands have deteriorated significantly since the most recent jack pine budworm outbreak in the early 1990's. Future regeneration of jack pine will require significant stand disturbance, either clearcutting or burning.

The overall health of red pine stands older than 20 years of age is excellent. However, red pine plantations less than 20 years are being affected by several agents including competing vegetation and frost. Further, the establishment of young red pine under or in the vicinity of large, overstory red pine has resulted in increased losses to shoot blight fungi, especially on the northern half of the Forest.

White pine numbers are slowly increasing on the Nicolet. Management techniques exist that could further increase the amount of white pine on the Forest despite localized blister rust, deer browsing, and white pine weevil concerns.

Spruce-Fir

The balsam fir resource is recovering from an intense spruce budworm outbreak that occurred during the 1970's and early 1980's. Today, balsam fir trees are very common but few old trees exist. Older balsam fir stands regularly have outbreaks of the spruce budworm, and another budworm outbreak should be expected once the current fir resource reaches 40 to 50 years of age. Current management practices, such as fire suppression, encourage balsam fir survival and expansion into many stands. Any significant overall increase in balsam fir could lead to more prolonged and intense spruce budworm outbreaks in future years.

In the Lakes States region, there is some evidence that plantation management of white spruce has exacerbated pest problems related to both spruce budworm and possibly needlecast diseases. Managing white spruce in mixtures versus pure plantations may reduce these problems.

Oak

The age distribution, heavily skewed to stands between 65 and 80 years of age, is a concern, especially for northern pin oak dominated stands. The risk of significant tree mortality increases as these stands age, especially with the recent establishment of gypsy moth in northeastern Wisconsin. Silvicultural practices are available that could increase overall vigor of oak stands and thus reduce the likelihood of widespread tree mortality.

Lowland Conifer

Overall, the lowland conifer forest type is in relatively good health. The tamarack resource is recovering well from widespread mortality that occurred between 1900 and 1940 as a result of two exotic defoliators, larch sawfly and larch casebearer. Today, both of these insects appear to be better regulated following the establishment of several exotic parasites. Black spruce is generally in good health, though some stands are affected by eastern dwarf mistletoe. Northern white-cedar, though a

common tree, is apparently experiencing regeneration problems. As with several other tree species, deer have been implicated, but other problems likely exist. On a local scale, flooding caused by beaver activity or road construction activities has been responsible for killing areas of all the swamp conifers.

Lowland Hardwoods

The composition of the lowland hardwood forest has been significantly altered with the greatly reduced status of American elm. The introduction of Dutch elm disease to the Forest in the 1960's has eliminated virtually all large elm trees. The loss of American elm has resulted in stands dominated more by black ash and red maple. This reduction in stand diversity may tend to promote insect and disease activity within this type. Black ash is currently recovering from a serious episode of decline that resulted from several weather-related events in the late 1980's and early 1990's.

Aspen-birch

Most aspen stands on the Nicolet are less than 40 years old and, therefore, from an age standpoint, in relatively good vigor. Because aspen stands rapidly deteriorate after age 50-60, tree mortality and stand decline should be expected as the aspen resource ages. The age distribution of paper birch stands is skewed heavily to older stands, which are susceptible to periods of increased mortality after droughts and insect outbreaks. In addition, few young stands are being initiated to replace the older, deteriorating stands. Gypsy moth and birch leafminers are exotic insects that will cause defoliation in the aspen-birch forest type in future years. This defoliation may lead to decreased growth and, in some cases, increased mortality in both aspen and paper birch.

The health of forest trees on and around the Nicolet has been surveyed and reported for many years (see Appendices 1 and 2). Further monitoring and surveys should be encouraged.

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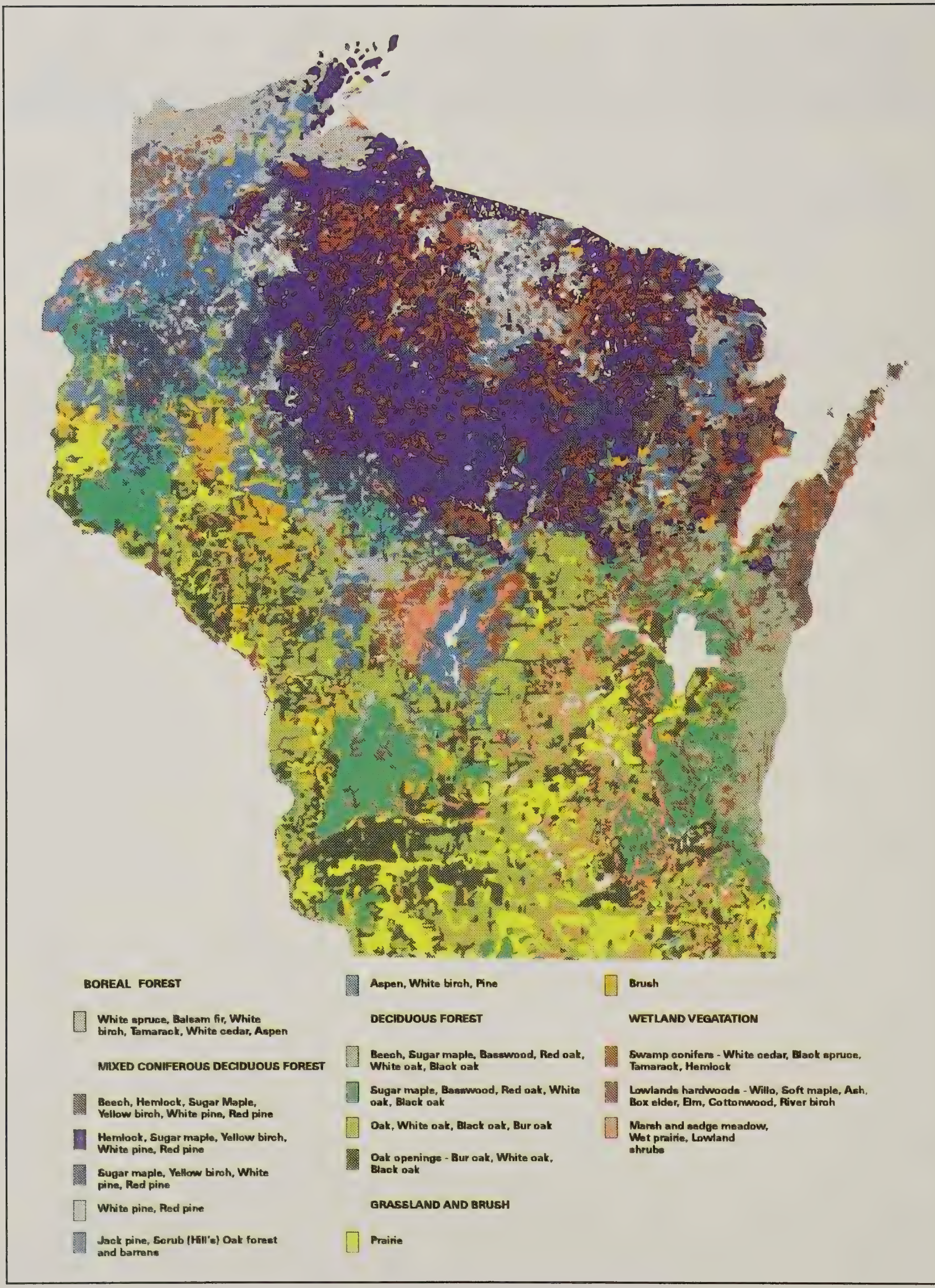

Original Vegetation Cover of Wisconsin. Map compiled by Robert W. Finley, reconstructed from the records of land surveys done prior to the time of major settlement.

INTRODUCTION

The Nicolet National Forest, located in northeastern Wisconsin (Figure 1), is composed of portions of the following counties: Forest, Florence, Langlade, Oconto, Oneida, and Vilas. The gross area within the boundaries of the Forest is approximately 973,000 acres. About two-thirds (655,000 acres) is federally owned. The most common forest type, sugar maple-dominated northern hardwoods occupies about 36 percent of the forested area, followed by the aspen-birch type which occupies roughly 22 percent of the forested area. Other important forest types include pine, spruce-fir, lowland conifers, lowland hardwoods, and oak. Roughly 23 percent of the Forest is in wetland, much of which is forested with conifers such as black spruce, tamarack, and white-cedar or hardwoods such as black ash and red maple.

Figure 1. The Nicolet National Forest is located in northeastern Wisconsin.

The area has a continental climate. Snow averages 50 to 60 inches per year, but snowfall varies greatly, with the lesser amounts on the southern end of the Forest and greater amounts in the north. Winters are extremely cold with an average daily temperature of 15°F and minimum winter temperatures from -45° F to -50° F. The growing season is short, ranging from 100 to 128 days, with an average daily temperature of 68°F and a total of 30-35 inches of precipitation annually.

This report is specific to the Nicolet National Forest, although the information presented is also relevant to surrounding areas. Much of this information comes from insect and disease surveys conducted on or in the vicinity of the Nicolet by the Forest Health Protection* unit of the USDA Forest Service. We obtained additional information from annual statewide forest pest conditions reports produced by the Wisconsin Department of Natural Resources. Also, information directly relevant to the Nicolet was gathered from several studies conducted and reported by Forest Service Research units as well as by researchers in the University of Wisconsin system. Finally, we obtained a great deal of information from staff, both past and present, on the Nicolet. For further information on how background material was collected for this report, see the Appendix titled "Monitoring Tree Health in Northeastern Wisconsin".

Purpose of the Report

We compiled scattered publications, office memos, research papers, and reports into one concise reference for current and future resource managers on the Nicolet as well as members of the general public interested in management of the Forest. This report provides information on disturbance agents that have affected the health of the major tree species on the Nicolet, and likely future events that could affect the Forest. It can help in future forest planning and in determining and evaluating management options and decisions for specific areas on the Forest.

* Formerly called Forest Pest Management.

Defining Health

The issue of the health of the forest is an important concept in the management of the Nicolet. Forest health can be viewed at a number of different scales ranging from individual trees to entire landscapes. The concept becomes more ambiguous as the complexity of the system increases. Healthy trees are relatively easy to define, but defining a healthy forest landscape is much more difficult.

Individual Trees

Dictionary definitions of "health" emphasize a single organism. One definition of health, "the state of an organism functioning normally without disease or abnormality," leads to a precise definition for an individual tree. Within this definition, a dead or dying tree is unhealthy.

Stands of Trees

The health of a stand, a relatively homogenous group of trees, is more complex. It relates both to the management objectives for the stand and to the long-term functioning of the organisms and ecological processes that function in and around that stand. Tree mortality does not necessarily indicate an unhealthy condition, as long as the rate of mortality is not greater than the capacity for replacement. Stand objectives, such as wildlife habitat, do not require a healthy condition for all trees in the stand. In fact, many wildlife species depend upon dead and/or dying trees for potential roosting, nesting, and feeding sites. Dead trees are not healthy, but they may be components of a healthy stand.

Landscapes/Ecosystems

The health of a forest landscape or ecosystem is even more complex than the health of a stand. Its health depends upon the sustainability of the biotic and abiotic processes within the landscape as well as upon our perception of ecological balance. Dead or dying trees and even dead and dying stands may not be healthy, but they can be components of a healthy landscape.

Tree Health on the Nicolet

The Nicolet National Forest can be viewed as a forest landscape. As such, it is very diverse, and evaluating its overall health is complex and far beyond the scope of this report. Therefore, we have chosen to evaluate and report on health at the level of individual trees or in some cases individual stands of trees. To place limits on our discussion, in this report, we do not consider dead or dying trees as healthy. We do this with the full understanding of the value that dead, dying, and decaying trees play in healthy forests. In that regard, disturbance agents that kill or weaken trees should not always be viewed as causing a forest health problem. Many of these agents are part of the natural cycle of forest communities and serve important roles in cycling nutrients and creating conditions for the regeneration of future forests.

We hope this report will serve as a useful reference in any further discussions on the broader issue of forest health. Many of the topics that are introduced are directly relevant to forest health including the role of native insects and pathogens; the effects of exotic organisms; the historical role of drought, wind, and other weather events; and the importance of the legacy left by past land-use practices in the area.

ORGANIZATION OF THIS REPORT

This report is organized into chapters:

Chapter 1

Historical Influences on the Nicolet National Forest discusses the history of the area that makes up the Nicolet. Events that occurred between 1850 and 1940 directly affected the makeup of the Nicolet today, and many of our current tree health concerns have direct ties to that period.

Chapter 2

Disturbances on the Nicolet introduces the major forest disturbance agents that operate on the Nicolet. The disturbances include abiotic events such as droughts, windstorms, and fires as well as biotic events such as insect and pathogen outbreaks. Human-caused disturbance is also discussed.

Chapter 3

Disturbance Agents by Forest Type discusses major health issues for each major tree species on the Forest. Tree species are grouped into the forest types in which they most often co-occur. We discuss what historically affected tree species, what affects them today, and what will probably affect them in the future.

Chapter 4

Looking Forward discusses what may influence the future health of tree species on the Nicolet.

Appendix I

Monitoring Tree Health in Northeastern Wisconsin describes how tree health information has been collected on the Nicolet as well as in surrounding parts of Wisconsin.

Appendix II

Annual Aerial Survey Maps provides a series of survey maps showing major defoliation or mortality periods since 1975.

Appendix III

Pictures of Major Pests includes photographs of the most commonly encountered insects and pathogens on the Nicolet.

Outwash
Outwash plains, terraces, fans, and valley trains. Mainly well-sorted and stratified sand and/or sand and gravel.

Ground Moraine
Till plains, thing drift, mostly till of relatively uniform thickness but discontinuous in some areas of older drift. Includes drumlins.

Glaciolacustrine Deposits
Lake sediments, including associated deltas, sand dunes, and organic deposits. Mainly sand, silt and clay.

Water

Pitted Outwash and Other Ice Contact Deposits
Pitted outwash plains, kames, eskers, crevasse fillings, and related features. Mainly sand and gravel with sorting and stratification locally poor.

End Moraines
Terminal, recessional and interlobate morains, mostly till and associated local ice contact deposits.

No Glacial Deposits

Figure 2. The glacial deposits of Wisconsin. Map published by the Wisconsin Geologic and Natural History Survey.

CHAPTER 1

HISTORICAL INFLUENCES ON THE NICOLET NATIONAL FOREST

The history of northeastern Wisconsin is very important in understanding the current status and health of forest trees on the Nicolet National Forest. Past historical events include several major disturbances that have influenced the current forest vegetation in the area. Further, many of these events will continue to influence forest composition and the health of tree species well into the future. Perhaps paramount among these past events is the glacial history of the area. The wide array of soils, drainage patterns, and landforms that resulted from glaciation directly affect the makeup of forest stands across the Nicolet. More recently, the logging era that occurred from about 1850 to the early 1900's had a significant impact on the status and health of the tree species found on the Nicolet. Logging altered the forest ecology of the region by initiating several significant disturbances that culminated in the removal of much of the forest overstory present in 1850. Logging brought with it roads and railroads that led to settlement and agriculture, much of which failed. Logging also led to widespread intense fires in the slash created by the cutting. Most stands on the Nicolet today developed after the destructive exploitation that occurred between 1850 and 1933, when the Nicolet National Forest was established. The status and health of many of the tree species in the area is directly tied to that legacy.

Glacial History

The landscape of the Nicolet and the surrounding area has been significantly altered by glaciation (Figure 2). It is believed that three separate glacial events occurred in Wisconsin, with the most recent occurring between 25,000 and 9,500 years ago. Ice and the associated meltwater from advancing and retreating ice sheets produced the major landforms of the area, including ground and end moraines, drumlins, pitted and unpitted plains, hummocks, eskers, kames, kettles, unpitted fans, and lacustrine plains. These landforms contain a great variety of glacial till, sand, and gravel that largely compose the surface material of the area. After the glaciers retreated, many exposed landforms were covered with a layer of loess (windblown sediments). This layer ranges from 1 to 3 feet thick across the Forest and is composed largely of silt-size particles. As glacial deposits and the loess cap have continued to weather, the present soils have developed across the landscape. Peat and mineral matter have accumulated in many of the lowlands.

The glacial history of the area is critical in any discussions of tree and forest health on the Nicolet. The wide array of soils, drainage patterns, and landforms that resulted from glaciation directly affect the makeup of forest stands. Certain tree species, such as sugar maple, basswood, and hemlock, are favored on more nutrient-rich, mesic sites that are associated with deposits of finer soil materials such as silt and clay. Other tree species, such as pines and oaks, dominate on the more nutrient-poor, drier sites that are generally sand deposits associated with outwash plains. Which species occur on certain sites, and how long and how well they grow, is predetermined to a large extent by what was left after the last glacial retreat.

Cultural History

People have lived in and around the area that is now the Nicolet National Forest since the retreat of the last glacier. Many of these people undoubtedly affected the forest makeup—initially by hunting and burning areas, later by trapping, and more recently by logging, farming, and grazing.

Influence of Native Americans on Vegetation

John Curtis, in his 1959 book titled "The Vegetation of Wisconsin," [1]estimated that about half of the vegetation present over the State of Wisconsin in the years before European settlement was directly influenced by anthropogenic activity. Fire was by far the most important tool with which the native people influenced the vegetation. Oak openings, oak and pine barrens, pine forests, and true prairies would not have been able to maintain their existence in the State without repeated fires[1]. Interestingly, one of the larger areas in the State that was probably the least influenced by fires was the mesic northern hardwood region of northern and northeastern Wisconsin, where much of the Nicolet exists today.

Arrival of Europeans

French explorer Jean Nicolet first arrived on the shores of Wisconsin in 1634, marking the beginning of a period of development and exploitation that would have the greatest impact on the area since the last glacial retreat. The activities of the next 300 years, perhaps more than anything else, would be directly responsible for the Nicolet as we know it today.

Fur-Trapping Era

Jean Nicolet came to Wisconsin to establish trade with the native people and obtain furs for the fashion-conscious European market. For the next 200 years trappers, traders, explorers, and missionaries became increasingly common. Beaver was the primary commodity, but furbearers of all types were shipped back to Europe in large numbers. By the early 1800's, beaver populations were significantly reduced and changing fashions put an end to the fur trade.

Pine Logging Era

Pine trees were harvested on what is now the Nicolet as early as 1835, although logging didn't really take off until the 1850's. Initially, pines were the only species harvested. Their large size and clear lumber made them ideal sawlogs, and at that time pine was widely believed to be far superior to other species for lumber (Figure 3). Also, pine logs could float and could be driven down the rivers—the only transportation available then—whereas hardwoods and other species often sank. By about 1870, all the easily obtained trees along lakes and steams were gone. However, railroads were pushing their way northward, which made previously inaccessible trees available for harvest. In 1887 the Soo Line Railroad built a line across what is now the Nicolet, roughly following Wisconsin Highway 8. Thanks to the railroad, lumbering in the vicinity of the Nicolet increased until it peaked around 1889, when mills at the mouth of the Menominee River sawed 500 million board feet of lumber. Pine logging continued until the early 1900's when the supply finally ran out.

Figure 3. Large, 45 inch diameter, 170 year old white pine cut on the Conner Logging Area, Nicolet National Forest.

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[1] Curtis, J. 1959. The vegetation of Wisconsin. Madison, WI: University of Wisconsin Press, 657 p.

Hardwood/Hemlock Logging Era

When the pine ran out, many loggers and lumberman moved on to the forests of western Wisconsin, northern Minnesota, and the Pacific Northwest. Many others, however, switched to hardwoods and hemlock. Hemlock bark was used in the leather tanning industry, and many trees were cut solely for their bark. Hardwood logging depended upon the railroads for transportation of materials. Logs were generally sawn locally, at smaller sawmills. Many of the larger pine mills had already been dismantled or destroyed by fire.

Destructive Fires

Logging created large areas covered with unused logs, broken trees, and dead branches (Figure 4). In these areas numerous fires occurred between 1850 and the early 1930's (Figure 5). Many of these fires were intentionally set by logging companies or farmers who thought the fires would help clear the land for future agricultural use. Some of these fires were the most intense, most destructive fires ever witnessed in North America. The Peshtigo fire occurred in northeastern Wisconsin in October of 1871. It burned an area of approximately 1.25 million acres and killed more than 1,000 people. Other large fires included a 1931 blaze that destroyed much of the community of Tipler in northwestern Florence County and a 1933 fire that burned a large area between the small community of Hiles and what is today Highway 55 in Forest County. Many areas on the Nicolet were repeatedly burned during this era. These fires destroyed many of the few remaining pine trees that could have served as seed sources for future pine-dominated forests. They created conditions for the establishment of many stands of paper birch, oak, and aspen that today are 60-80 years old. These fires undoubtedly destroyed much of the organic matter in many areas and altered the soil microorganisms and other soil properties, which has affected trees survival and growth on the Nicolet during the last 60-100 years.

Figure 4. Area along the Eagle River - Alvin Road cut over by the Thunder Lake Lumber Company, Circa 1937.

Figure 5. Fire damage on the Argonne Unit, Nicolet National Forest, 1933.

Agriculture in the Northwoods

In the early 1900's, it was generally assumed that agriculture would follow in the wake of logging. Much land was sold as "farms" and many settlers attempted to farm some of the area (Figure 6). However, agriculture never gained much of a foothold in the vicinity of the Nicolet. Clearing the land and removing stumps was so difficult that very little land was cultivated. Furthermore, the poor quality of the soil for agriculture provided very little yield. Many ambitious farmer/settlers fell prey to land-speculation companies promises of good soil and long growing seasons, only to find that they had purchased burned-over, over cut land that in many cases would never produce a crop. Many of these so-called farms eventually became tax-delinquent and ended up back in the hands of the counties.

Figure 6. An average farm home in northern Wisconsin, circa 1920.

Birth and Development of the Nicolet National Forest

In 1928, the Oneida Purchase Unit of 151,680 acres in Oneida, Forest, and Vilas Counties was the first land acquired for the yet unnamed national forest. In 1932, additional acreage was acquired—an additional 68,000 acres in the Oneida Unit, and 204,800 acres in Forest, Vilas, Oconto, and Langlade Counties, known as the Oconto Unit. In 1933, the acquired lands were officially designated the Nicolet National Forest. Land acquisition has continued from that time.

With the establishment of the national forest, fire protection became a high priority. A transportation system, fire trails, and fire towers were established, and the number of fires quickly dropped. With the drop in fires, and the termination of grazing and other farming practices, much of the land quickly began to revert to trees (Figure 7).
The conditions were very conductive to the establishment of early pioneer species such as quaking aspen, paper birch, and oak. Many of the northern hardwood-dominated areas had not burned as frequently or as intensely and young sugar maple stands quickly became established in these areas. Pines were rare because many of the seed sources had been destroyed by logging and the intense fires that followed. However, pine was reintroduced into many areas by

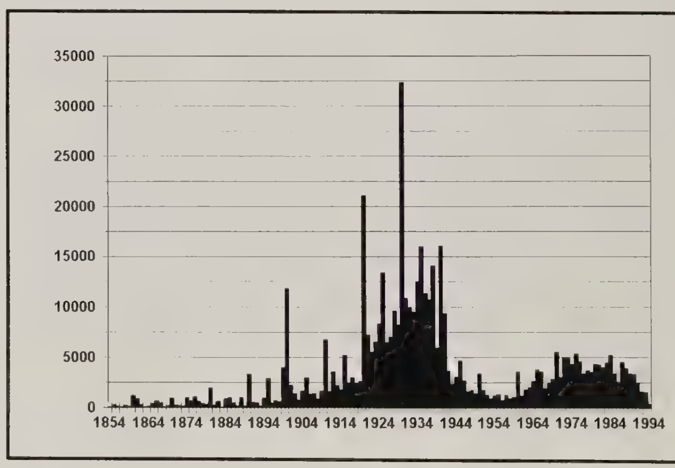

Figure 7. The year of origin for current stands on the Nicolet. The vast majority originated between 1920 and 1940.

planting programs started in the 1930's. Enrollees of the Civilian Conservation Corps, which was created in 1933, performed fire control duties, constructed roads and buildings, and planted trees (Figure 8), and other duties. Many of the trees planted were red, jack and white pines. The tree planting programs did reestablish pine stands in many parts of the Nicolet, but these monoculture plantations were quite different from the original pine stands. Large areas of even-aged red and jack pine led to outbreaks of pine feeding sawflies and the Saratoga spittlebug. Today, many of these plantations are 60-70 years old. For jack pine this is old age, and these stands are quickly deteriorating due to insect and disease attack. White pine blister rust, an exotic disease, became established in Wisconsin in the 1930's and made the management of white pine more difficult. In addition, many of the developing hardwood stands had an early history of grazing or high grade logging, which resulted in trees with preexisting health problems. For these reasons and many others, it is important that we consider the history of the Nicolet in any discussion of the status and health of tree species on the Forest.

Figure 8. Trees being planted on denuded lands by CCC crews in the 1930's.

CHAPTER 2

DISTURBANCES ON THE NICOLET

"Windfall, alone or with the other agents of mortality, fire, drought, glaze storms, insect or fungus infestation and senescence, keeps the forest in a constant state of flux which results in a continuous variation in composition, both in space and time, within the limits of the species present."

Forest Stearns, 1949

Abiotic Causes of Disturbance

Wind

Historically, the most important disturbance agent on the Nicolet was probably wind. Wind-related disturbances varied a great deal in the size of the area they affected and the severity of the damage they caused. An original vegetation map for the period from 1850 to 1860, recreated by R.W. Finley from survey notes, shows some 2-3 percent of the forest as blowdown (Figure 9).[2] Researchers have estimated that in the northern hardwood forest of northeastern Wisconsin in presettlement times, 12,000 acres were destroyed annually by catastrophic windthrow.[3] Probably equally important were the much more common wind events that created small gaps by toppling single trees or small groups of trees. Because of wind disturbance, the northern forest was not one large homogeneous block of trees, but rather a mosaic of trees and stands of various age classes in various stages of succession.

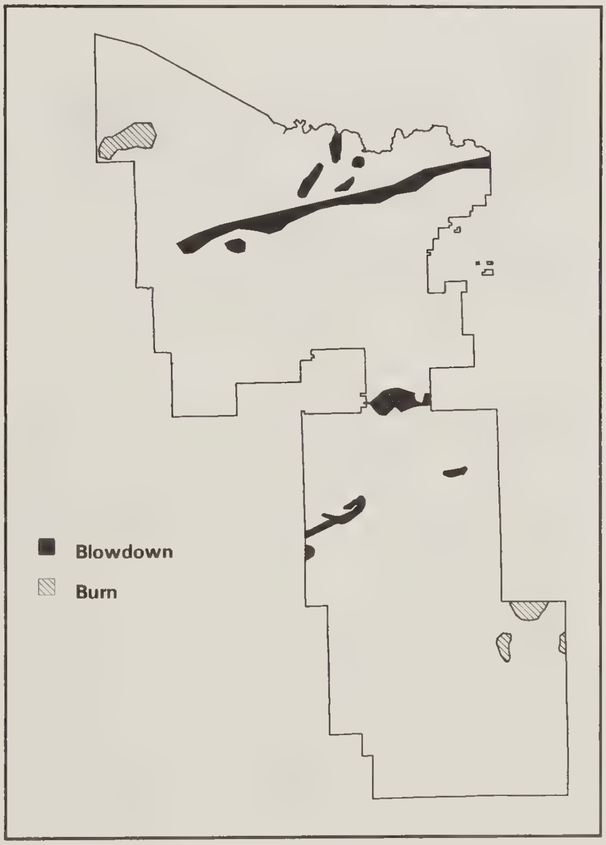

Figure 9. Major wind and fire disturbances, 1850 to 1860.

The weather-related disturbance regimes of today differ somewhat from those of the past because of the changes in the age, composition, and distribution of the trees making up the Forest. Wind has become a less significant source of disturbance because the Nicolet now consists of more wind-resistant even-aged stands composed of younger trees and contains fewer stands with large numbers of older and super-canopy trees. Further, current forest management and harvesting tends to remove vulnerable trees and generally promotes

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[2] USDA Forest Service. 1986. Final Environmental Impact Statement: The Nicolet National Forest.

[3] Canham,C.D.; Loucks, O.L. 1984. Catastrophic windthrow in the presettlement forest of Wisconsin. Ecology. 65(3): 803-809.

wind-firm stands. Nonetheless, small-scale wind disturbances continue to operate, causing gaps and promoting diversity within the forest. Catastrophic wind events are also still with us. The famous Fourth of July storm in northern Wisconsin in 1977 had winds well over 100 miles per hour that blew down some 76 million board feet of timber on 527,700 acres of timberland, including 2,000 acres of old-growth northern hardwoods on the Flambeau River State Forest (Figure 10). Other recent examples include three tornadoes that touched down on the neighboring Menominee Indian Reservation in April, 1984, destroying 3,172 acres of forestland; and very high winds in July, 1997, that heavily damaged approximately 2,600 acres on the Reservation. A review of weather records indicates that only three tornadoes have occurred on the Nicolet National Forest since 1880.[4]

Figure 10. Blowdown disturbance that occurred July 4, 1977.

Drought and Flood

Extremes of rainfall and soil moisture occur periodically on the Nicolet (Figure 11), often with serious consequences. Episodes of drought and severe moisture stress occur at fairly regular intervals over time. Drought is important because it causes root mortality, from which trees recover very slowly. During this several-year recovery period, trees are especially vulnerable to attack by insects or pathogens, which can ultimately kill them. Thus, mortality often shows up several years after the drought, which sometimes confuses the diagnosis of forest health problems.

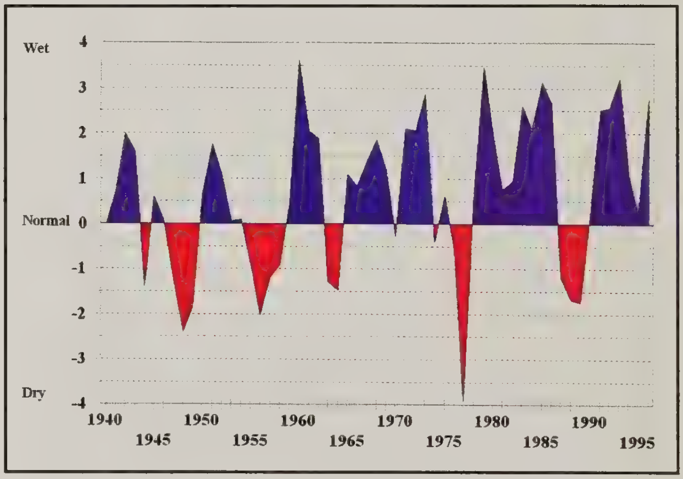

Figure 11. Palmer drought index, northeastern Wisconsin.

Trees vary in their susceptibility to drought, depending on depth of the root system, age, current condition, and type of soil the tree is growing in. Those trees with shallow root systems, such as paper birch, are very susceptible to drought. Seedlings and older trees are particularly vulnerable. Healthy vigorously growing trees are less vulnerable than those weakened by previous defoliation or other stress. Sandy soils are more prone to drought because they dry out much faster than heavier soils.

The historic role of drought as a disturbance agent on the Nicolet is not well documented. Undoubtedly periodic droughts occurred that caused varying amounts of mortality. We know that much of the Forest was covered with the northern hardwood type, which is not particularly susceptible to drought. Some portions of the Forest, however, do have sandy soils that very likely experienced drought stress more often and to a greater degree than the rest of the Forest. These sites largely supported pine types and not surprisingly are some of the most fire prone.

[4] Fischer, C. 1996. Use of multi-temporal remote sensing data to detect forest canopy change on the Nicolet National Forest. University of Wisconsin, Madison. Masters Thesis. 64 p.

Today, drought is an important source of disturbance on the Forest, primarily because of the change in forest composition to pioneer species that are more susceptible to drought, such as paper birch. The most recent severe drought on the Forest, in 1987-1988, severely stressed aging paper birch all across the Lakes States. In 1990, the Wisconsin DNR reported that, "Birch mortality was at an all time high in northern Wisconsin."[5]

In contrast to drought, several successive years of above average rainfall can raise the water table and create a different set of problems. An elevated water table saturates the soil in the root zone and prevents gaseous exchange, causing oxygen deprivation and eventually root death. Trees are not able to respond by quickly growing new roots higher in the soil profile and subsequently become stressed. If soil moisture remains high, the trees may die, or more commonly be invaded by secondary organisms, causing them further stress. A rise in the water table may have been responsible for several episodes of yellow birch dieback in Upper Michigan.

Large-scale flooding does not occur on the Forest, but it can occur in localized areas along rivers and streams that are subject to damming by beaver. It is fairly common on the Forest today to see isolated pockets of mortality as a consequence of such dam building. Historically, many stream side areas were probably alternately forested and flooded depending upon the amount of beaver activity in the area.

Fire

With the exception of the fire era that followed the logging of the late 1800's, fire was apparently not a major cause of disturbance on what is now the Nicolet. Much of the Forest was covered with a relatively non-flammable northern hardwood type. Infrequently, fire was able to enter northern hardwood stands after blowdowns, drought, insect outbreaks, or other disturbances that killed trees. In this way, opportunities were created for the establishment of pioneer or early successional species. Otherwise on the Nicolet, fire was largely restricted to pine types, which usually existed on drier sandy sites.

Today, fire continues to play a relatively minor role even though the Forest contains much less of the northern hardwood type than it did in the past, and supports greater proportions of early and mid-successional species, particularly conifers such as balsam fir, spruce, and pine. These species are somewhat more prone to fire than the hardwood forests they replaced. Furthermore, today's increased human activity brings more potential ignition sources. Nonetheless, fire has not become significant on the Forest probably because of fire suppression. When fires do occur, they tend to be small, usually less than 10 acres.

Harvesting

Before 1850 there was essentially no harvesting on the Forest. While native people lived in the area and used a wide variety of forest products, their lack of technology greatly limited the size of the material they were able to work with. Consequently, the larger trees were not harvested to any great degree, and harvesting had very little impact on the Forest.

The historic logging era changed all that as timber harvesting suddenly became an important source of disturbance in the forest. The effects from this era are still very much present, and its legacy will continue to influence the Forest far into the future. For an in-depth discussion of the influences of historic logging, see Chapter 1.

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[5] Wisconsin Department of Natural Resources. 1990. Forest pest conditions in Wisconsin. Annual Report.

Historic logging was very different from the harvesting practiced today. Historically, vast acreages were cut with little thought or concern for the future. Today, harvesting still occurs on the Forest, but the emphasis today is on sustainability and on regenerating future stands. Harvesting is used as a management tool to manipulate stands. Several different harvesting strategies and techniques are used to favor different tree species and to accomplish different management objectives. For example, clear-cutting is used to manage sun-loving pioneer species such as aspen and red pine. Single-tree selection harvesting favors shade-tolerant, late-successional species like sugar maple and beech, whereas group selection harvesting favors mid-successional species like basswood and yellow birch.

Biotic Causes of Disturbance

Insects and Diseases

Insects and fungi were a significant component of the presettlement forest. Their role in this system was generally positive, eliminating decadent or unthrifty trees and decomposing those that had died. Cover types such as aspen and jack pine probably suffered significant damage as a result of insect activity, but the impact as a whole was less severe because of the relative lack of these species on the Forest. Native pathogens, similarly, probably grew to epidemic levels only occasionally. They too, generally existed in stable populations, causing scattered mortality throughout the Forest, but rarely causing extensive mortality in any given area. Decay fungi were probably more active historically than they are today due to the greater proportion of older trees in the past.

Today, the change in forest composition to more early successional species and an age-class structure that features younger forests has altered the significance of insects and pathogens. Early-successional species are generally more prone to insect damage, with outbreaks occurring more frequently than on later successional species. This change has made insects, such as forest tent caterpillar and spruce budworm, of primary importance on the Forest.

Exotic Organisms

The insect and pathogen situation today is far more serious than in the past because of exotic organisms that have been introduced to the Nicolet, either intentionally or accidentally, and that have since become established. Exotic organisms pose a serious threat to the ecological balance that has developed over thousands of years of evolution. Many of the most important tree health issues facing the Forest today are the result of exotic introductions. Examples of exotic forest pests on the Nicolet include:

Diseases	Insects
White pine blister rust	Birch leafminers
Dutch elm disease	Larch sawfly
Butternut canker	Larch casebearer
	Introduced pine sawfly
	Introduced basswood thrips
	Gypsy moth

Exotic introductions are not limited to insects and pathogens; many exotic plants have found a home on the Nicolet, including such plants as purple loosestrife and spotted knapweed. Wherever an exotic plant grows, a native plant has been displaced.

The white-tailed deer is a natural component of the forests on the Nicolet. Deer numbers, however, have fluctuated considerably since presettlement times. Deer populations and distribution vary over the long term due to the availability of suitable habitat, and they vary over the short term because of weather conditions.[6] The present deer population on the Forest is estimated at 22,000 animals, or about 21 deer per square mile. This number is higher than estimates of presettlement deer numbers of 14 deer per square mile, but lower than a peak during the 1940's of over 45 deer per square mile in northeastern Wisconsin.[7] The cause of these extreme fluctuations is explained by the forest history of northern Wisconsin. The mature northern hardwood forest type that predominated in presettlement times provided relatively poor deer habitat. However, post-logging cutover lands and agricultural clearings provided excellent habitat that supported tremendous population growth. Finally, the abandonment of farming and the maturing of the forest provided conditions less favorable for deer and the numbers began to drop. A low point was reached during the late 1960's and early 1970's, primarily due to a series of severe winters. The relatively mild winters since that time have helped deer numbers build to today's levels.

The 21 deer per acre mentioned above is a Forest-wide average. In reality, deer tend to favor certain habitats over others, deer densities may be several times higher in areas such as winter deeryards. High deer concentrations can severely damage browse species in these areas. On the Nicolet, and in the Lake States in general, cedar swamps are favorite winter deeryards. Repeated browsing can kill or stunt trees and, therefore, affect regeneration of species such as white-cedar that occur in areas with seasonally high deer populations. On the Nicolet, the lack of regeneration of several tree species has been partially attributed to high deer populations. These include northern white-cedar, white pine, hemlock, and yellow birch. However, the extent to which deer are responsible for the regeneration problems affecting these species is not yet clear. So whether the present population levels are inhibiting the achievement of forest objectives is still an unanswered question.

Conclusion

From the retreat of the glacial ice 10,000 years ago to last summer's insect defoliation, many disturbance factors have influenced the Forest. The Nicolet, as we know it today, is the direct result of all of these past disturbances and the Forest will continue to be shaped by disturbance. Some of these disturbances will be intentional, such as harvesting; some, like disease outbreaks and insect infestation, will be predictable; and others like tornadoes or exotic introductions will occur unexpectedly or with serious consequences.

[6] Doepker, R.V.; Beyer, D.E.; Donovan, M. Jr. 1995. Deer population trends in Michigan's Upper Peninsula. *In:* Hemlock ecology and management. Proceedings of a regional conference on ecology and management of eastern hemlock. University of Wisconsin - Madison: 200 p.

[7] McCafferty, K.R. 1995. History of deer populations in northern Wisconsin. *In:* Hemlock ecology and management. Proceedings of a regional conference on ecology and management of eastern hemlock. University of Wisconsin - Madison: 200 p.

Chapter 3

DISTURBANCE AGENTS BY FOREST TYPE

Northern Hardwoods

Composition

For this report, we are placing the following tree species into the northern hardwood type: sugar maple, basswood, yellow birch, hemlock, butternut, white ash, and American beech. On the Nicolet, this type is dominated by sugar maple.

Importance

On the Nicolet, the northern hardwood forest occupies more than 223,000 acres and makes up approximately 36 percent of the Forest (Figure 12).

Figure 12. Location of the northern hardwood type on the Nicolet.

Forest Type Summary

- Sugar maple appears to be in good health at this time. However, the other major species in the northern hardwood type do have health issues that may create problems in maintaining stand diversity in the type. These concerns include:

Inadequate regeneration is a problem with both yellow birch and hemlock. Deer have been implicated, but other contributing factors appear to be involved as well.

Butternut canker is causing widespread mortality across the forest, and there is a very real possibility of losing butternut as a tree species on the Nicolet.

Introduced basswood thrips, an exotic insect, has caused prolonged defoliation of basswood on the Forest. This insect, along with another exotic defoliator, gypsy moth, could cause reduced growth or localized mortality in basswood.

• Both yellow birch and sugar maple have experienced periods of widespread tree decline. Generally, periods of decline have been followed by a periods of recovery, and mortality has not been excessive. Large-scale weather fluctuations and insect defoliation are the most likely causes of decline.

American Basswood

Introduced basswood thrips, an exotic defoliator, has recently caused widespread, chronic defoliation, and another exotic insect, gypsy moth, is a future defoliation threat. These two exotics, along with the activity of several native defoliators, may lead to increased episodes of defoliation in basswood. This would result in decreased growth rates and could prevent basswood from maintaining its place in the overstory of some northern hardwood stands.

Basswood is a large, rapid-growing tree that is usually found on nutrient-rich, mesic sites. It is long-lived and often occurs in the canopy of late-successional hardwood forests along with sugar maple. It occasionally grows in pure stands, but is more often found growing in association with sugar maple, white ash, northern red oak, and red maple. It reproduces most commonly by stump sprouts. Basswood is considered tolerant of shade but is not as tolerant as sugar maple. Because of its ability to sprout from stumps, it can readily recover from disturbances such as windstorms and logging.

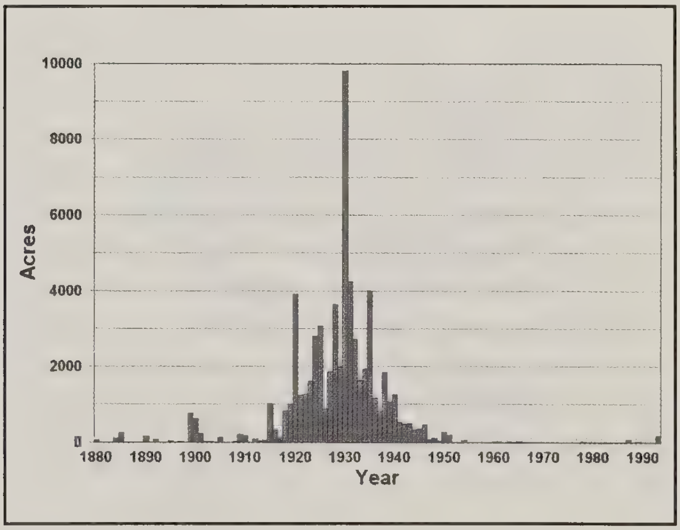

Figure 13. Year of origin of the sugar maple/ basswood type on the Nicolet.

Age Class Distribution

Because basswood rarely grows in pure stands, its age class distribution on the Nicolet is difficult to ascertain. However, a good estimate is the sugar maple/basswood group (Figure 13). The vast majority of stands in that group originated between 1920 and 1935, making them 60-75 years old. Younger basswood trees are present in a number of forest types and since basswood readily sprouts following cutting, no problems regenerating the species have been reported.

Historical Disturbance Agents

Historically, basswood had no major insects or pathogens that affected it on a large scale. It was occasionally defoliated by native caterpillars such as the linden looper, spring cankerworm, and several leafroller species, which would have had little impact other than slowing growth for a short period of time. Basswood, then and now, does not have any secondary insects or pathogens that invade and kill it during periods of stress. In the past, its major disturbances were probably wind and very occasionally fire.

Recent Disturbance Agents

Introduced basswood thrips is an exotic insect that was first reported in Wisconsin defoliating approximately 2,000 acres in Forest and Oneida Counties in 1980. This outbreak expanded to include most of the basswood resource across northern Wisconsin by 1988. The outbreak then subsided and

observable defoliation was not reported in the State until 1996 when an outbreak of approximately 18,000 acres was reported on the Nicolet (Figure 14). Despite repeated early spring defoliation in the 1980's, widespread mortality of basswood has not been reported. Those trees that did die had generally been suppressed.

Harvesting of basswood has increased in Wisconsin in the past 10 years. It is considered a valuable species for timber production.

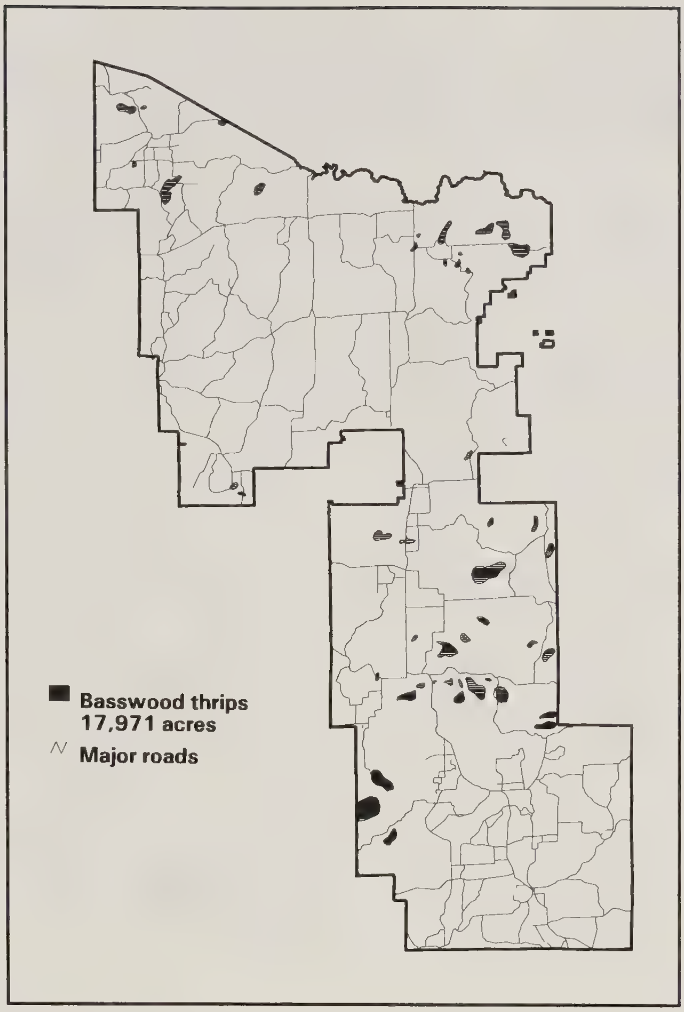

Figure 14. Aerial survey results showing introduced basswood thrips defoliation, 1996.

Future Disturbance Agents

The future levels of activity of introduced basswood thrips and their impact cannot be predicted at this time because the insect has not been present on the Forest or in the Great Lakes Region long enough. However, it seems likely that introduced basswood thrips will continue to cause occasional defoliation of basswood. In addition, basswood is considered highly preferred by gypsy moth caterpillars, another serious potential defoliator that is becoming widely established in northeastern Wisconsin. Furthermore, several native caterpillar species will continue to have occasional outbreaks, resulting in localized areas of basswood defoliation. Historically, the amount of defoliation caused by native defoliators was probably inconsequential, but when combined with additional defoliation by the introduced basswood thrips and eventually by the gypsy moth, basswood defoliation could become a much more serious health concern.

Because of the presence of introduced basswood thrips and gypsy moth, future harvesting activity, specifically crown release by thinning, may be needed to help basswood maintain its dominant or codominant role in many stands. Basswood often grows as a component of other hardwood stands; the other tree species in these stands will not be defoliated by introduced basswood thrips, and most will not be defoliated by gypsy moth (i.e., sugar maple). The regular periods of basswood defoliation may result in growth loss, which could lead to suppression by the surrounding, non-defoliated trees. In addition, harvesting should benefit regeneration because basswood sprouts so well from cut stumps.

Major Insects and Pathogens

Introduced basswood thrips, *Thrips calcaratus*, is of European origin. The basic biology and life history of this tiny sucking insect have been poorly studied because it causes very little damage in its native European range. In Wisconsin, introduced basswood thrips has one generation per year and overwinters in the soil as an adult. The adults emerge in middle April to early May and appear on the buds of basswoods as the buds begin to swell. They feed on the newly opening leaf tissue, which results in shredded leaves and aborted buds (photo - Appendix III). Eggs are laid in the leaf veins and the immature insects develop on the remaining basswood leaves in late spring and

early summer. Larvae drop to the soil by midsummer where they complete development into adults and remain until the following spring. What regulates populations of introduced basswood thrips in the Great Lakes Region is still unknown, and what the insects long-term prognosis is remains undetermined.

Native caterpillars also feed on basswood and can occasionally cause defoliation. These caterpillars include the linden looper, *Erannis tiliaria*; fall cankerworm, *Alsophila pometaria*; basswood leafroller, *Pantographa limata*; and the maple-basswood leafroller, *Sparganothis pettitana*.

Gypsy moth, *Lymantria dispar*, caterpillars will readily feed on basswood. However, the long- term effects of gypsy moth on basswood are poorly understood because most gypsy moth impact studies have been conducted in oak-dominated stands. On the Nicolet, basswood is more often associated with sugar maple than oak, though it does co-occur with northern red oak in some stands.

Summary

Basswood is capable of a long life span and historically had few serious insect pests and no serious pathogens. However, one exotic defoliator — introduced basswood thrips — has recently caused widespread chronic defoliation and a second exotic insect — gypsy moth — is a future defoliation threat. Therefore, the following is considered the most important health concern for basswood:

•Increased periods of defoliation - the presence of introduced basswood thrips, gypsy moth, and native defoliators may lead to numerous periods of defoliation in basswood. This defoliation would likely result in decreased growth rates and may prevent basswood from maintaining dominant or codominant status in some stands.

American Beech

The beech resource on the Nicolet is currently experiencing no significant health problems. However, the tree is apparently much less prevalent today than it was historically.

American beech is a long-lived hardwood species, capable of living 300 to 400 years, and is an occasional component of both the upland and lowland hardwood forests on the southern half of the Nicolet. The Nicolet is on the edge of the native range of beech, consequently the trees are generally of lesser quality and insufficient quantity to be economically important. Beech was never widespread across the Forest, although before the logging era it was a common component of the forests in the Lakewood area. Today it exists in lesser quantities, occurring only in the Lakewood and Laona Ranger Districts, usually in localized concentrations mixed with other northern hardwoods. American beech is a late-succession species that grows well in the shade of the northern hardwood forest. Beech produces an edible nut, providing a food source for wildlife within northern hardwood stands, and contributes to the overall diversity of the forest.

Age Class Distribution

Most beech trees on the Forest are found in the sugar maple/beech/yellow birch cover type. The majority of these stands originated before 1940. Small beech trees are relatively common on nutrient-rich sites on the southern end of the Nicolet.

Historical Disturbance Agents

American beech is favored by a lack of stand disturbance. Historically, it was probably most prevalent in areas that had very infrequent fires or that lacked other large-scale disturbances. Repeated disturbance tends to eliminate beech. Although beech does not have any major insect or pathogen problems, it does host more species of decay fungi than nearly any other North American hardwood. Heart rots were very common and contributed to increased breakage and windthrow of older trees. Frost cracks were common in the northern portions of its range, including Wisconsin, and served as entry points for decay fungi. Logging and agricultural land-use in the early part of the 20th century greatly reduced the amount of beech on the Forest.

Recent Disturbance Agents

No major disturbance agents have significantly impacted American beech on the Nicolet. Beech numbers on the Forest have not yet recovered to pre-logging era population levels. Because beech is a late successional species, there probably has not been enough time for appropriate stand conditions to develop that favor its development.

Future Disturbance Agents

One potential threat to beech is beech bark disease. This exotic disease has been responsible for killing thousands of mature beech in Maine, New Hampshire, Vermont, and New York, and it is now moving through Pennsylvania and West Virginia. Beech bark disease has not yet been found on or near the Nicolet, its future introduction is possible.

Major Insects and Pathogens

Beech bark disease is a disease complex caused by the native fungi *Nectria coccinea* var. *faginata* or *N. galligena* and an introduced scale insect, *Cryptococcus fagisuga*. Neither organism by itself is capable of causing significant damage, but together they are killing thousands of trees throughout New England (Figure 15). Trees are initially infested with the scale, which can be identified by a white waxy "wool" on the bark of the tree. Infestation by scales predisposes the tree to invasion by the fungus. Ironically, once the tree is invaded by the fungus, it becomes uninhabitable to the scale. It is the fungus that ultimately kills the tree.

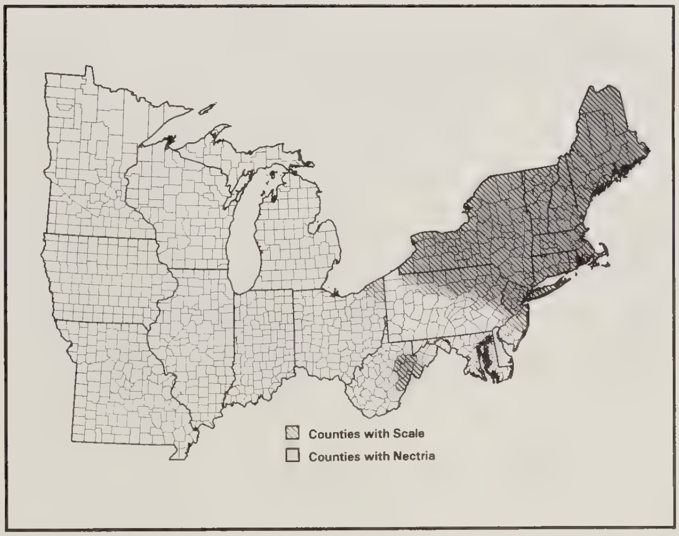

Figure 15. Distribution of beech bark disease, 1996.

Summary

American beech is a relatively minor component of the Nicolet, but it does provide valuable mast within the northern hardwood type and contributes diversity to the Forest. It currently has no major health problems. The introduced disease complex, beech bark disease, is a potential threat, but this disease has not yet been introduced into the Forest.

Butternut

The existence of butternut is currently threatened by butternut canker. This fungal disease has been responsible for the death of thousands of butternut trees all across the Eastern U.S. There is no known cure for this disease, and it may eliminate the species.

Butternut is a medium-size, short-lived tree that seldom reaches 75 years of age. It is a component of the northern hardwood forest and the lowland hardwood forest, and it often grows in mixtures with aspen. In general, butternut is not a very significant component of most stands, but it does contribute to the diversity of the forest and provides valuable mast for many animals. On the Nicolet, butternut can be found clustered in localized areas on the Eagle River, Laona, and Lakewood Ranger Districts. The Nicolet is on the very northern boundary of the natural range of butternut, which partially accounts for its relative scarcity. Butternut has been thrust into the spotlight in recent years because of the advent of butternut canker. Butternut canker is a fungal disease of unknown origin that has been killing thousands of trees throughout the tree's range. This disease is a very serious threat to the butternut resource.

Age Class Distribution

Because butternut is such a minor component of the Forest, few records are kept specifically on butternut. Recent inventories indicate that most butternut trees on the Nicolet are in the older age classes.[8]

Historical Disturbance Agents

Little specific information exists on the historical disturbance agents important to butternut. Butternut was subject to periodic damage from general hardwood defoliating insects and fungal pathogens, though none are known to have been of major importance. A disturbance agent like wind that created canopy gaps was actually beneficial because seedlings are intolerant and require direct sunlight to develop. Later, farming and grazing were disturbances that similarly benefited butternut. The species quickly colonized farm fields and pastures when agricultural activities were abandoned during the early part of the 20th century.

Recent Disturbance Agents

Butternut canker was first reported in Wisconsin in 1967. Since that time, the disease has spread to nearly every county where butternut is found (Figure 16). It was first observed near the Nicolet in

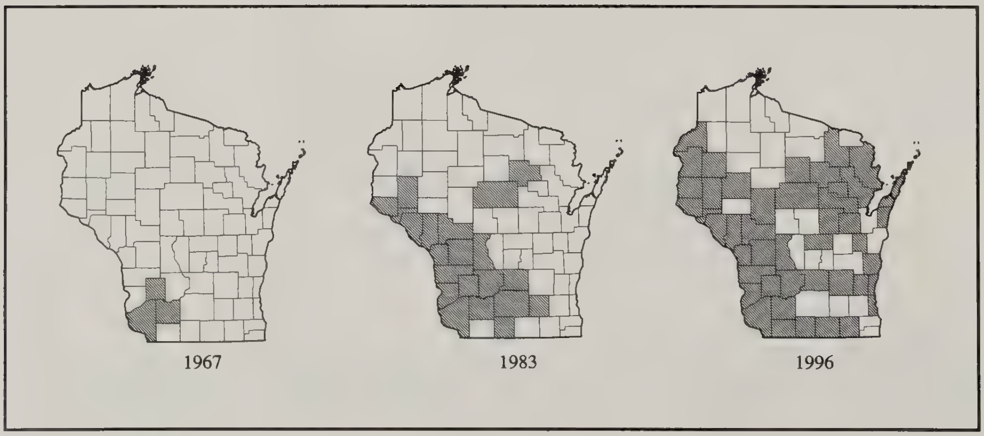

Figure 16. The distribution of butternut canker across Wisconsin, 1967 through 1996.

[8] Forest Inventory and Analysis, USDA Forest Service, 1996 Nicolet data.

1983. A Wisconsin DNR study reported that 91 percent of butternut in all age classes were infected with butternut canker.[9] In 1993, the harvest of butternut trees was restricted on national forests in Regions 8 and 9 to protect potentially valuable genetic material. Currently, the impact of butternut canker has far overshadowed that of any other disturbance agent of butternut.

Future Disturbance Agents

Butternut canker will continue to kill butternut trees. Efforts are underway to propagate potentially resistant butternut, although it remains unclear whether any real resistance exists. There is a very real danger that butternut as a species may become extinct. Any additional stresses that befall this species will probably serve to hasten this process.

Major Insects and Pathogens

Butternut canker, caused by the fungus *Sirococcus clavigignenti-juglandacearum*, is a fatal canker-causing disease (photo - Appendix III). The fungus is capable of infecting trees through natural openings in the bark and causes perennial cankers to form. Cankers can be found anywhere on the tree, but occur primarily on the lower bole. Eventually many cankers form, ultimately girdling the tree. Short-distance dissemination of the disease is mainly by rainsplash. Long-distance dissemination of the disease does occur, but the mechanism is unknown, although insects and birds have been suggested as likely vectors. There is no practical control for this disease, but the following guidelines will help to preserve potentially resistant trees in the management of butternut:[10]

1. Retain trees with more than 70 percent live crown and less than 20 percent of the combined circumference of the stem and root flare affected by cankers.

2. Harvest dead or declining trees to salvage the quality and value of the wood, or maintain the trees in the forest for their wildlife value.

3. Retain trees free of cankers with at least 50 percent live crown and growing among diseased trees. These trees may be resistant and have value for propagation by grafting or breeding.

Summary

In the northern hardwood forest, butternut is a relatively minor, but ecologically important component whose very existence is threatened by butternut canker. This disease has spread throughout the natural range of butternut, killing up to 80 percent of trees in many areas. A few trees appear to be resistant to the disease, though it is still unclear whether resistance actually exists.

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[9] Cummings-Carlson, J. 1993. Butternut: are there any trees left? Woodland Management. Spring: 11-12.

[10] Ostry, M.; Mielke, M.; Skilling, D. 1994. Butternut-strategies for managing a threatened tree. General Technical Report NC-165. St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station. 7 p.

Eastern Hemlock

The amount of hemlock on the Nicolet is greatly reduced from historical levels. Achieving adequate regeneration continues to be a problem.

Eastern hemlock is an extremely long-lived tree, capable of living more than 500 years, that historically was a major component of many forest stands in northeastern Wisconsin. Mature hemlock-northern hardwood forests once dominated much of the Nicolet, especially on mesic sites. Hemlock is usually found in close association with yellow birch, but also occurs in either relatively pure stands or in mixtures with white and red pine. It is considered extremely shade tolerant and can withstand suppression for as long as 400 years. In heavy shade, it grows very slowly, but responds well to overstory release even at older ages. On the Nicolet, mature hemlocks are much less common today than they were before 1850. In the early 20th century, hemlock was extensively logged for its bark, which was used by the leather tanning industry. Subsequently, a lack of hemlock regeneration has been identified as a concern in many areas.[11]

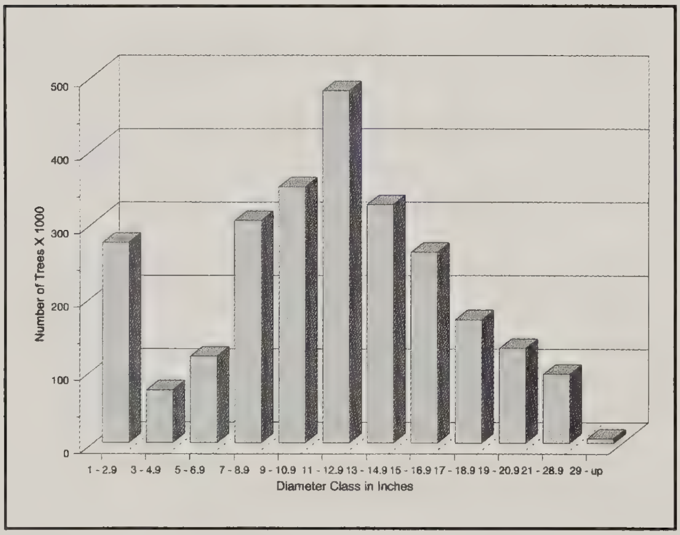

Figure 17. Number of hemlock by diameter class, Nicolet National Forest, 1996, FIA Inventory.

Age Class Distribution

Because hemlock trees can be very old, yet still very small in diameter, determining an age class distribution is difficult. However, because of hemlock's ability to withstand suppression and still readily respond to release, all small diameter trees have the potential to become members of the overstory. The 1996 Forest wide- inventory found that most hemlock trees on the Nicolet are larger than 7 inches in diameter (Figure 17). Therefore, increasing the hemlock component will require a significant increase in smaller trees for eventual recruitment into the larger size classes.

Historical Disturbance Agents

Drought and wind-caused disturbances were likely the major factors that affected hemlock trees historically. Periods of windthrow would have provided abundant breeding material for hemlock borer, a small beetle that breeds in dead and weakened hemlock trees. If a period of drought coincided with a wind storm, hemlock mortality could have been quite extensive as occurred on the Menominee Indian Reservation, which is adjacent to the Nicolet, in the 1930's when approximately 138 million board feet of hemlock timber died. Drought can also kill hemlock seedlings. Outbreaks of insects, such as the hemlock looper and spruce budworm, could have also caused occasional periods of tree mortality. Hemlock is not tolerant of heavy defoliation and can die following a single year of severe (90 percent) needle loss. However, hemlock looper has not had a severe outbreak in Wisconsin this century, although it has been active in Michigan's Upper Peninsula.

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[11] Waller, D.M.; Alverson, W.S.; Solheim, S. 1995. Local and regional factors influencing the regeneration of eastern hemlock. In: Mroz, G.; Martin, J., eds. Hemlock Ecology and Management: Proceedings of a regional conference on ecology and management of eastern hemlock; 1995 September 27-28; Iron Mountain, MI. Madison, WI: University of Wisconsin, Department of Forestry: 73-90.

Older hemlock trees would have had contained a good deal of wood decay. In most trees, this did not cause mortality, though it would have led to increased wind breakage. Animal damage, specifically browsing by snowshoe hares and white-tailed deer, could have seriously damaged young hemlock. However, hare populations are cyclic with years of low browsing, and before the logging era, deer populations were lower than they are currently.

Hemlock trees were heavily harvested on the Nicolet between 1850 and 1920. Further, the widespread fires that occurred after the logging period would have killed many young hemlocks. Finally, very high deer populations occurred in northeastern Wisconsin during the early 1940's and would have created very difficult conditions for hemlock regeneration to survive under.

Recent Disturbance Agents

Presently, a lack of hemlock regeneration is considered a regional problem with hemlock[12]. High deer populations are considered one of the most likely reasons for poor regeneration, though a lack of large woody debris for seed beds and other environmental factors are also very likely involved. Drought may also be causing regeneration difficulties, though this is not well documented.

In northeastern Wisconsin, no major insect or disease outbreaks have occurred in hemlock stands in the recent past. However, a 1994-1995 outbreak of the hemlock looper in Michigan's Upper Peninsula resulted in 200 acres of dead hemlock. Harvesting activity does occur on occasion. Stand disturbance, which can be attributed to harvesting as well as weather, has caused localized mortality of hemlock. Hemlock trees have relatively shallow root systems that are quite sensitive to disturbance.

Future Disturbance Agents

Periods of dry, hot weather could affect the establishment of young hemlock. In addition, older trees could be affected, especially if an additional stand disturbance coincides with drought. Any periods of major stress caused by weather, defoliation, or harvesting activity could lead to an increase in tree mortality by the hemlock borer and Armillaria root disease.

Deer populations, if they remain at high levels, could affect regeneration of hemlock, especially in localized areas such as deer yards.

Gypsy moth is a potential threat mainly to understory hemlock trees that occur in or near a stand of aspen or oak. Although hemlock is not a preferred food for gypsy moth, it will be consumed by older larvae in the absence of other food sources, such as during large outbreaks. Hemlock are particularly sensitive to defoliation and mortality is highly likely when defoliation exceeds 90 percent.

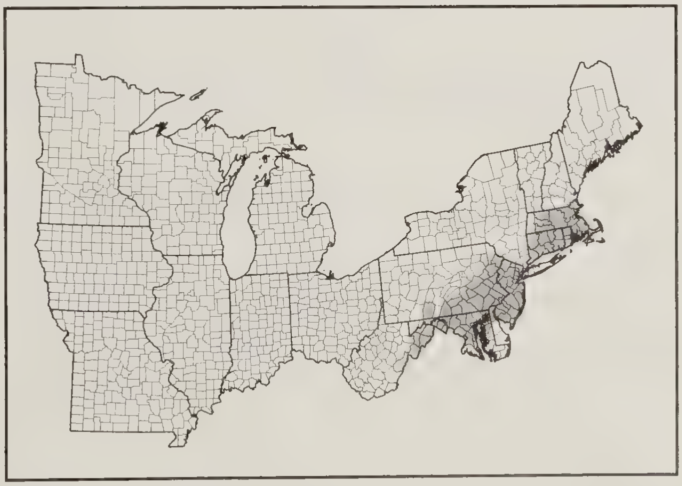

Figure 18. Distribution of Hemlock woolly adelgid, 1996.

Another potential exotic threat to hemlock is the hemlock woolly adelgid. This insect, native to Asia, is currently killing hemlock trees in the Northeastern United States (Figure 18). Low winter temperatures have retarded the spread

[12] Crow, T.R. 1995. The social, economic, and ecological significance of hemlock in the Lake States. In: Mroz, G.; Martin, J., eds. Hemlock ecology and management: Proceedings of a regional conference on ecology and management of eastern hemlock; 1995 September 27-28; Iron Mountain, MI. Madison, WI: University of Wisconsin, Department of Forestry: 11-17.

northward, but the adelgid could possibly expand its range into northeastern Wisconsin eventually.

Major Insects and Pathogens

Armillaria root disease is commonly found infesting the root systems of dying or recently killed hemlock trees. *Armillaria* fungi are ubiquitous in most forest soils and readily infect root systems of trees that are severely stressed from drought or insect defoliation. Infection of the root system by *Armillaria* fungi further stresses trees and can cause their death outright or it can lead to successful infestation by the hemlock borer, which eventually kills the tree.

Hemlock borer, *Melanophila fulvoguttata*, is a native beetle whose immature stage feeds under the bark of weakened hemlock trees. Hemlock may become weakened or stressed after drought, insect defoliation, major stand disturbance such as windthrow, or in some cases, harvesting activity. On the Menominee Indian Reservation, wind damage in the early 1930's initiated a hemlock borer outbreak that killed approximately 135 million board feet of timber by 1938. Smaller infestations were also reported on the Nicolet and Chequamegon National Forests. Drought during that same period intensified the outbreak by further stressing trees[13]. Hemlock borer-infested trees are easily identified in the late winter when woodpeckers remove much of the bark in search of the immature beetles.

Hemlock looper, *Lambdina fiscellaria fiscellaria*, is a native caterpillar species that historically has been a serious defoliator of hemlock in the Northeastern United States and adjacent Canada, though it has not been a serious problem in Wisconsin. In 1994-1995, the hemlock looper completely defoliated and killed 200 acres of mature and understory hemlock at Tahquamenon Falls State Park in Michigan's Upper Peninsula. Hemlock loopers eat both new and old foliage and trees die readily if defoliation levels exceed 90 percent.

Summary

Before the 1850's, hemlock was a major species on much of the Nicolet, especially on mesic, nutrient-rich sites. Today, hemlock is much less abundant, and adequate regeneration has been difficult to obtain. Deer browsing has been identified as one potential problem affecting regeneration, though many other factors are probably also involved. Hemlock trees are capable of very long life spans, and older hemlock trees should persist if they can become established as an overstory species on the Nicolet. Some mortality in both young and old hemlock should be expected during drought, which are not unusual on the Nicolet. The hemlock woolly adelgid will be a serious future threat to the hemlock resource if this insect can establish itself in northeastern Wisconsin. The major health concerns of hemlock are:

- Adequate regeneration - finding ways to obtain and maintain adequate regeneration will be required to reestablish hemlock in many areas on the Nicolet.
- Deer browsing - the effect that white-tailed deer population levels are having on the regeneration of hemlock needs to be determined.

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[13] Secrest, H.; MacAloney, H.; Lorenz, R. 1941. Causes of the decadence of hemlock at the Menominee Indian Reservation, Wisconsin. Journal of Forestry. 39: 3-12.

Sugar Maple

At this time, the overall health of the sugar maple resource is good, though the quality of the trees will continue to be of concern to some wood industries. Periods of decline in sugar maple have occurred in the past and are likely to occur again in the future. However, large-scale mortality has not been associated with prior declines.

Sugar maple largely defines the northern hardwood forest. It is a long-lived climax species capable of achieving ages of 300-400 years. Sugar maple-dominated stands can occupy a site for hundreds of years barring major disturbance. Late-successional species by definition are able to thrive underneath their own overstory, and it is very common to find the ground carpeted with sugar maple seedlings in a northern hardwood stand. These seedlings persist in the understory for many years, ready to take advantage of small gaps that will allow them to reach the canopy. Because many other northern hardwood species require large gaps to successfully reach the canopy, sugar maple can often eliminate them in the absence of any major disturbance.

Age Class Distribution

On the Nicolet, most sugar maple stands originated after turn-of- the-century logging (Figure 19).

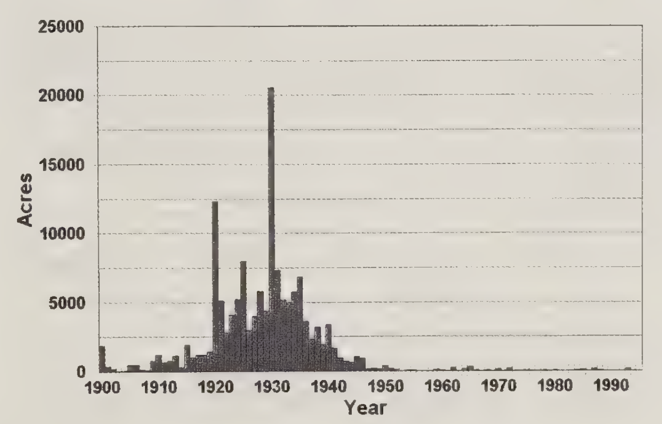

Figure 19. Year of origin of sugar maple dominated stands on the Nicolet.

Historical Disturbance Agents

Sugar maple was relatively free of major disturbance agents in the past. Fire was never able to have much of an impact because these forests are not particularly flammable and rarely dry out. Although sugar maple is host to many insects and pathogens, none regularly caused widespread mortality. Wind was the only disturbance agent that was able to cause much of an impact. Records indicate that blowdowns did occur and that it was only on the heels of such a disturbance that fire was able to enter most sugar maple stands.

Many of the sugar maple-dominated stands that originated in the early 1900's developed under less than ideal conditions. Some stands were grazed, others developed from trees slowly invading open fields and pastures, and many had a history of fires. Such conditions often resulted in open-grown stands that were more likely to have insect and disease problems than well-stocked stands. Several shoot and bud mining insects attacked sugar maples growing in full-sunlight and this resulted in many forked trees. Further, sugar maple borer, a woodboring beetle, attacked many open-grown trees. Wounds from the borer acted as entry points for decay and led to breakage in wind storms. Finally, many trees developed frost cracks and sunscald. The result was a sugar maple resource that in many cases had a great deal of defect and decay. That legacy can still be found in many stands in northeastern Wisconsin.[14]

[14] Miller, W.; Kessler, K.; Ohman, J.; Eschle, J. 1978. Timber quality of northern hardwood regrowth in the Lake States. Forest Service. 24: 247-259.

Recent Disturbance Agents

Today, sugar maple remains free of serious disturbance agents, although episodes of maple decline have been reported in northeastern Wisconsin. The most severe decline episode was in Florence County in 1956-57.[15] Insect defoliation was considered the major cause of this decline, which resulted in significant tree mortality in localized areas. Defoliation by two leafroller caterpillar species and the maple webworm combined with drought to severely stress maples. Armillaria root disease then invaded the declining trees and killed them. Another period of maple decline, though not as severe, was reported on the Nicolet in 1979.[16] Surveys indicated only scattered small pockets of dead and declining trees on the Eagle River and Florence Ranger Districts. Drought that occurred in 1976-77 probably initiated this episode. The following chart describes maple decline:

Characterization of Maple Decline

Stage 1	**Branch dieback**, one of the earliest symptoms. The crowns appear thin.
Stage 2	**Foliage chlorosis** and **wilt** are followed by brown or red coloration of the leaves.
Stage 3	**Epicormic sprouting** — many small sprouts grow on twigs or the main stem.
Stage 4	**Tree mortality** is the final stage. Trees of all ages may be killed.

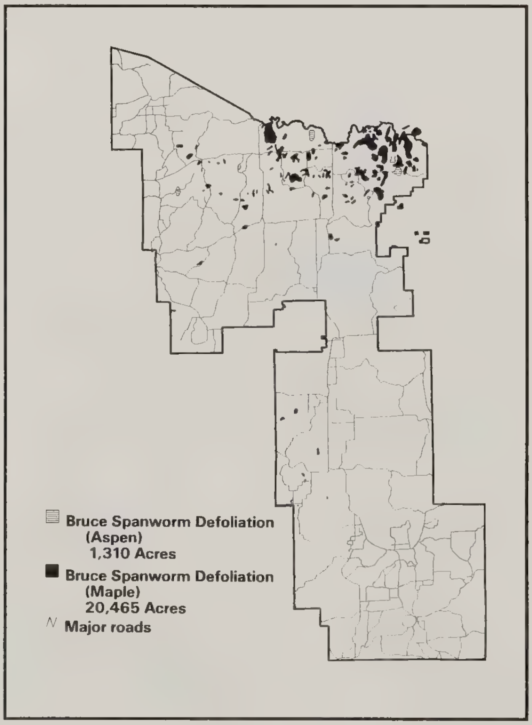

Figure 20. Aerial survey results showing Bruce spanworm defoliation of sugar maple and aspen, 1986.

Outbreaks of defoliators in sugar maple are not very common, especially over large areas. The most recent large outbreak occurred between 1985 and 1987 and involved the Bruce spanworm (Figure 20). This outbreak did not lead to any apparent forest decline despite being widespread and lasting for more than one year.

A study of sugar maple health was conducted in Wisconsin in 1987-88[17]. That survey reported that the sugar maple resource of northern Wisconsin was generally in excellent health. Dead and declining trees made up about 2 percent of the overall sugar maple forest. Armillaria root disease was most often associated with these dead and dying trees. Though in good overall vigor, many sugar maple stands do have a large percentage of "poor quality" trees. The reasons for this, discussed earlier under Historical Disturbance Agents, relate mostly to past land-use practices.

[15] USDA Forest Service. 1964. The causes of maple blight in the Lake States. Research Paper LS-10. St. Paul, MN: Lake States Forest Experiment Station. 15 p.

[16] Munson, S.; Robbins, K. 1980. An aerial survey to detect spruce budworm damage on the Nicolet, and maple dieback on the Ottawa and Nicolet National Forests, 1979. NA-FB/P-13. Broomall, PA: USDA Forest Service, Northeastern Area, State & Private Forestry. 9 p.

[17] Mielke, M.; Rezabek, C.; Cummings-Carlson, J.; Gillespie, A. 1991. Survey to assess the health of sugar maple and other northern hardwoods across a pH gradient in Wisconsin, 1987-1988. Publication No. AM-052 91. Madison, WI: Wisconsin Department of Natural Resources. 38 p.

Future Disturbance Agents

Sugar maple will continue to be host to a wide variety of insects and pathogens, though none should cause serious problems. On occasion, defoliators will reach outbreak levels. If an outbreak is prolonged or corresponds with a drought, some sugar maples will likely decline. However, the overall levels of mortality and growth loss should be low. The arrival of gypsy moth is not a threat to sugar maple. The only potential exotic threat at this time is pear thrips, which has been found in Wisconsin (Figure 21). Pear thrips severely defoliated almost 2 million acres of sugar maple in the Northeastern U.S. in 1988. However, that outbreak quickly subsided, and the future threat from this insect is still unknown.

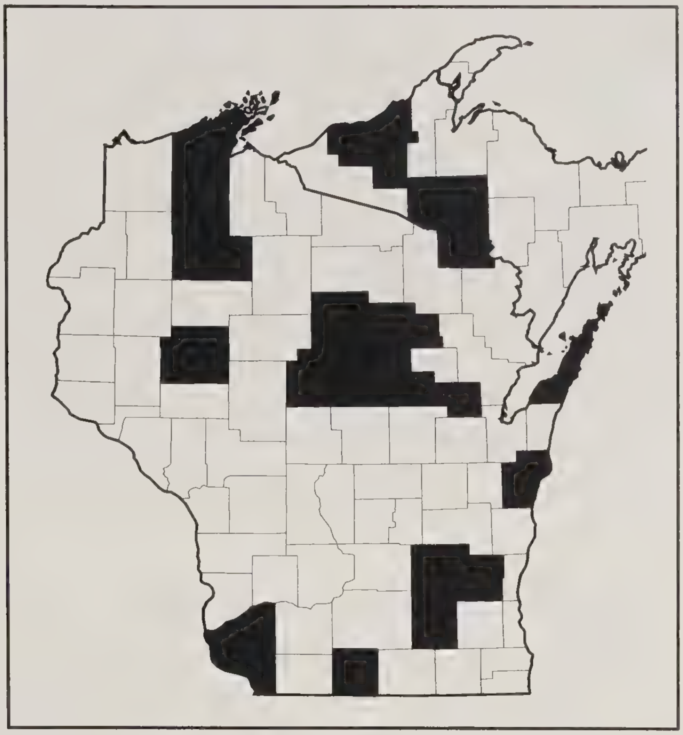

Figure 21. Pear thrips were located in the shaded counties during a 1990 Wisconsin DNR survey.

The quality of the sugar maple resource will continue to be of concern to some wood industries. Stand management, in the long run, could improve the quality of many stands. Decay organisms will become more common as the sugar maple resource ages.

Major Insects and Pathogens

Sugar maple borer - *Glycobius speciosus* is a native wood-boring beetle. Attacks do not kill trees, but they can cause structurally weak areas that break during wind or ice storms. Poorly stocked stands are particularly attractive to the sugar maple borer, which attacks the tree generally between 4 and 20 feet up on the main bole. Loose bark and swollen callus areas are characteristic evidence of attacks (photo - Appendix III). Management recommendations include avoiding poor stocking conditions, growing sugar maple on "good" maple sites, and preventing grazing of stands. Removal and destruction of "brood trees" may help in some instances.

Defoliators - Several caterpillars feed on sugar maple in the Lake States and have, at times, caused noticeable defoliation. In northeastern Wisconsin, these have included:

Defoliator	Scientific Name	Outbreak Years
Maple leafroller	*Sparganothis acerivorana*	1960-62
Lesser maple leafroller	*Acleris chalybeana*	1960-62
Maple webworm	*Tetralopha asperatella*	1960-62
Orange humped mapleworm	*Symmerista leucitys*	1961
Bruce spanworm	*Operophtera bruceata*	1985-87
Forest tent caterpillar	*Malacosoma disstria*	1955-57, 59-60 and 86-89

This information was taken from annual reports of forest pest conditions in Wisconsin, 1952-89, produced by the Wisconsin DNR.

Nectria canker - *Nectria galligena* causes cankers on a wide variety of hardwoods. Infection occurs through wounds, usually on young trees, so most cankers are found on the lower portions of the trunk. Cankers are usually perennial, with a new layer of host material laid down every year, forming the classic target shape that gives this disease its other common name, the target canker. Control is difficult and amounts to selective removal of infected trees. Many young cankers may be inconspicuous, making it difficult to assess the extent of the problem in a stand.

Eutypella canker - *Eutypella parasitica* is the most common canker disease on sugar maple (photo - Appendix III), accounting for considerable mortality in pole-size stands in the Lake States. The disease often infects through wounds, such as those caused by the sugar maple borer, or through branch stubs. Trees less than about 5 inches in diameter are often girdled; on larger trees perennial cankers develop. There is often extensive decay behind the canker face, and stem breakage at this point is very common. Old, large cankers cause a distinctive deformation of the stem of the affected tree, forming a shape somewhat reminiscent of a cobra's head. Eutypella canker, unlike Nectria canker, is confined to maples. Control consists of removing the infected trees to reduce the amount of inoculum present in a stand.

Summary

At this time, the overall health of the sugar maple resource is good, but the quality of many trees is low. Sugar maple lacks any major exotic pests at this time. Periods of decline in sugar maple have occurred in the past and are likely to occur again in the future. These events will generally follow an insect outbreak or a significant drought. Tree mortality should not be excessive after these declines. The following is the most important health concern for sugar maple:

- Tree quality - quality can be improved and the incidence of decay reduced by following management practices that minimize injury to residual trees during harvest activities.

Yellow Birch

The yellow birch resource is very sensitive to large-scale disturbances and has been prone to subsequent periods of dieback and decline. Despite this, tree mortality has been the exception rather than the rule. Regeneration of yellow birch may be a problem that requires further study.

Yellow birch is a relatively slow-growing, long-lived tree that grows on well-drained, nutrient-rich, mesic sites. It is rarely found in pure stands, but is more frequently found as a component with other northern hardwoods such as sugar maple, basswood, and beech, as well as with hemlock. Despite often being associated with shade tolerant trees such as sugar maple, yellow birch itself is considered intermediate in shade tolerance. Disturbance of the litter layer is needed for successful germination and seedling establishment, and some stand disturbance is needed to provide adequate sunlight for birch regeneration to gain a foothold in the canopy.

Age Class Distribution

Because yellow birch rarely grows in pure stands, its age class distribution on the Nicolet is difficult to ascertain. However, a good estimate is the year of origin graph for the sugar maple/ beech/yellow birch type (Figure 22). The vast majority of stands in that group originated between 1920 and 1935, making them 60-75 years old.

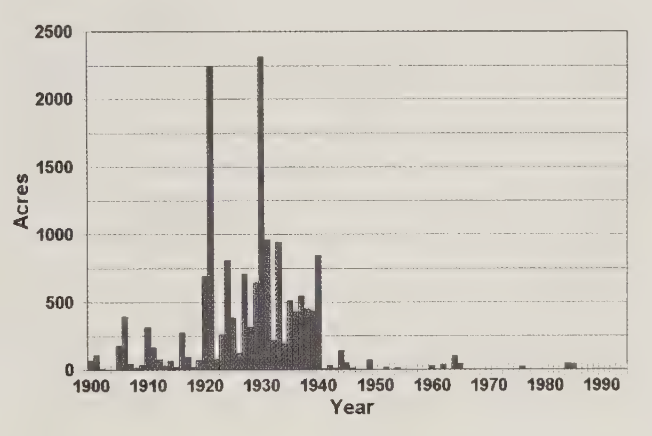

Figure 22. Year of origin for stands in the sugar maple/beech/yellow birch type on the Nicolet.

Historical Disturbance Agents

The maintenance of yellow birch in most northern hardwood stands in the past would have depended upon some level of disturbance that provided the proper seed bed and canopy release required by young yellow birch. Windthrow was the most likely disturbance agent to generate canopy gaps beneficial to yellow birch.

Decay fungi were probably common in older yellow birch. Although they are not generally associated directly with tree mortality, decay fungi can lead to greater incidence of windthrow and stem breakage after ice and wind storms.

Older yellow birch are considered very sensitive to stand disturbance. Periods of decline and dieback of yellow birch have occurred several times in northern Wisconsin and neighboring Michigan during the 20th century.[18] Most of this dieback occurred in older and larger trees. Apparently, several different types of disturbance can cause dieback in yellow birch. These have included:

- Elevated water table - a period of dieback from 1954 to 1963 in Michigan's Upper Peninsula appears to have been initiated by an unusually high water table in 1954. In addition, a period of dieback in the early 1940's in the same area followed high water table reports between 1939 and 1941.[19]

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[18] Kessler, K.J., Jr. 1965. Dieback of managed, old-growth northern hardwoods in Upper Michigan, 1954-1964: a case history. Plant Disease Reporter. 49: 483-486.

[19] Kessler, K.J., Jr. 1967. Dieback not a cause of mortality or reduction of growth or quality in Lake States northern hardwoods. Journal of Forestry. 65: 892-893.

• Defoliation by insects, frost, and drought - these three agents may have combined to cause the most recent period of yellow birch decline in Wisconsin, between 1984 and 1990.[20]

• Harvesting activity - dieback in yellow birch stands has occurred following harvesting activity. Such activity may lead to soil compaction; root damage; increased light penetration into stands; and a reduction in transpiration rates, which leads to wetter soils. Crown deterioration in yellow birch generally increases with the intensity of the cut.[21] Though harvesting activity can induce dieback, it is not the cause for regional periods of dieback that affect uncut stands as well as cut stands.

• Seed production - crown dieback in yellow birch has followed years in which seed production has been very high.[22]

Though periods of dieback seem to have occurred with some regularity in the Lake States, little tree mortality has been reported. Further, the dieback seems to have been isolated to branches in the upper crowns, and stain and wood decay in the main stem have not been reported after episodes of dieback. Following periods of dieback, a period of recovery generally has occurred.

Recent Disturbance Agents

The most recent period of decline in yellow birch in northeast Wisconsin was apparently initiated in 1984 as a result of insect defoliation and frost. The drought of the late 1980's further contributed to the decline. Affected areas were reported in Florence County, just east of the Nicolet boundary and to the south on the Menominee Reservation. Scattered mortality was reported from 1984 through about 1990, although most affected trees only experienced branch dieback.

Recently, the regeneration of yellow birch has been identified as a concern. This concern has been further substantiated by the 1996 Forest-wide inventory that showed a reduction in the number of yellow birch trees on the Forest between 1983 and 1996.[23] The reasons for the difficulty in getting young yellow birch established are not well understood. To become established, yellow birch requires some disturbance of the litter layer, and current management practices in northern hardwood stands may fail to sufficiently disturb the site. In undisturbed stands, yellow birch will not be able to successfully regenerate and compete with the much more shade tolerant sugar maple. In addition to having a difficult time getting established, yellow birch can be heavily browsed. It is a preferred food source for both white-tailed deer and snowshoe hare. Hare populations are cyclic and would allow some yellow birch seedlings to become established during years with low hare populations. Deer populations, however, are not cyclic and have been much higher during the past 20 years than they were historically. The effects of browsing on yellow birch are poorly documented.

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[20] Giese, R.L.; Martin, A.J. 1989. Birch decline: an assessment of yellow birch problems in northeastern Wisconsin. Staff Paper Series No. 40. Madison, WI: University of Wisconsin, Department of Forestry. 34 p.

[21] Godman, R.M. 1958. Changes in yellow birch top-dying Upper Michigan 1954-1957. Technical Note No. 527. St. Paul, MN: USDA Forest Service, Lake States Forest Experiment Station. 2 p.

[22] Kessler, K.J., Jr. 1969. Top-dying of yellow birch associated with seed production. Plant Disease Reporter. 53: 694-697.

[23] Forest inventory and analysis, USDA Forest Service, 1996 Nicolet data.

Future Disturbance Agents

Occasional periods of decline will very likely continue due to all of the various stressors that affect older yellow birch. Decline periods should be viewed with the understanding that recovery generally follows. However, disturbance from harvesting can compound the decline syndrome. Therefore, harvesting activities in yellow birch stands should be avoided during periods of decline so that the problem is not exacerbated.

A more pressing future concern may be adequate regeneration of yellow birch. Management practices that create canopy gaps and provide some soil disturbance may be required to increase regeneration. Continued high deer populations may inhibit regeneration efforts and appropriate control measures may need to be taken if maintaining or increasing the yellow birch resource is a management objective.

Major Insects and Pathogens

Bronze birch borer, *Agrilus anxius*, is a native beetle species that thrives on weakened birch. The immature stage feeds in winding tunnels under the bark, destroying the ability of a tree to transport food and water. Healthy, vigorous birch can resist attacks. Weakened trees are readily invaded and most eventually die, though it may take 2-3 years for an infested tree to be killed. Older yellow birch trees exposed after logging or those occurring in open-grown stands are often attacked by bronze birch borer.

Decay fungi — older yellow birch and younger trees that have been injured are frequently infected by one or more of the many wood rotting fungi that attack yellow birch. Some of the more important decay fungi include *Phellinus igniarius* and *Ganoderma applanatus.* Yellow birch is also host to several canker rot diseases that cause cankers in addition to decay, making them more obvious in the field. The most important of these is the very conspicuous *Inonotus obliquus*, or sterile conk, which produces a large black growth that protrudes from the tree. This fungus causes extensive decay of yellow birch.

Summary

Yellow birch is a highly desired member of the northern hardwood forest type. At this time no major insect or pathogen problems threaten yellow birch, but adequate regeneration of the species may be a problem. Regeneration problems apparently relate more to site disturbance issues than to insect or pathogen problems. However, deer populations may have some negative impacts on regeneration, especially in localized areas. In older yellow birch stands, periods of decline have occurred over large areas and are likely to continue to occur into the future. Yellow birch is very sensitive to several types of forest disturbance, including frosts, drought, excess moisture, and insect defoliation. However, tree mortality following these decline periods has not been excessive and recovery has generally followed. Harvesting activity in yellow birch stands can cause localized decline in remaining trees, but it can also serve as a necessary disturbance agent that provides an adequate seed bed and sufficient light for successful regeneration. The following are the most important health concerns for yellow birch:

- Stand disturbance - can lead to periods of decline in yellow birch. Disturbance can be caused by many events including human activities such as harvesting.

- Regeneration - yellow birch is a member of the northern hardwood forest that requires some site disturbance for successful regeneration.

- Deer browse - the role that deer populations play in affecting regeneration of yellow birch is not adequately documented. Browsing may reduce yellow birch regeneration.

White Ash

The white ash resource on the Nicolet is currently experiencing no major health problems.

White ash is a medium to large tree that is a common but never abundant species of many of the northern hardwood forests on the Nicolet. It is found growing on deep, nutrient-rich, well-drained soils. Young seedlings tolerate heavy shade, but lose that ability as they age. Therefore, white ash is considered a shade intolerant species. White ash regeneration is favored by a disturbance such as windthrow that removes the canopy. The Nicolet is on the northwestern edge of the natural range of white ash in the U.S.

Age Class Distribution

The vast majority of stands containing significant amount of white ash were established between 1915 and 1935. Recent FIA data indicate a marked increase in white ash stems less than 3 inches in diameter since 1983.[24]

Historical Disturbance Agents

Although white ash is susceptible to a wide variety of insects and diseases, it is unlikely that any of these agents caused extensive mortality in the past. Wind was probably a disturbance agent that benefitted white ash by allowing sunlight to enter hardwood stands.

Recent Disturbance Agents

White ash remains relatively free of any destructive insects or pathogens.

Future Disturbance Agents

White ash trees on the Nicolet are expected to remain free of significant disturbance agents. Ash yellows is a recently recognized tree disease that has been affecting primarily white and green ash across the Eastern and Central United States. Ash yellows causes a general decline and premature death of infected trees. It has not caused widespread mortality to date and its eventual impact is uncertain. This disease has been reported in southern and western Wisconsin, but to date no cases have been reported on the Nicolet. The establishment of gypsy moth on the Nicolet does not pose a threat to the white ash resource because ash trees are avoided by this insect.

Major Insects and Pathogens

White ash on the Nicolet currently does not host any major insects or pathogens.

Summary

White ash is a locally important component of the northern hardwood forests on the Nicolet. At this time, it is free of any major insects or pathogens that might cause reduced growth or mortality. Ash yellows is a possible future threat, but the risk of the disease is still unclear.

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[24] Forest Inventory and Analysis, USDA Forest Service, 1996 Nicolet data.

Composition

For this report, we are placing the following tree species into the pine type: red pine, jack pine, and eastern white pine.

Importance

On the Nicolet, the pine type occupies nearly 67,000 acres and makes up approximately 11 percent of the Forest (Figure 23).

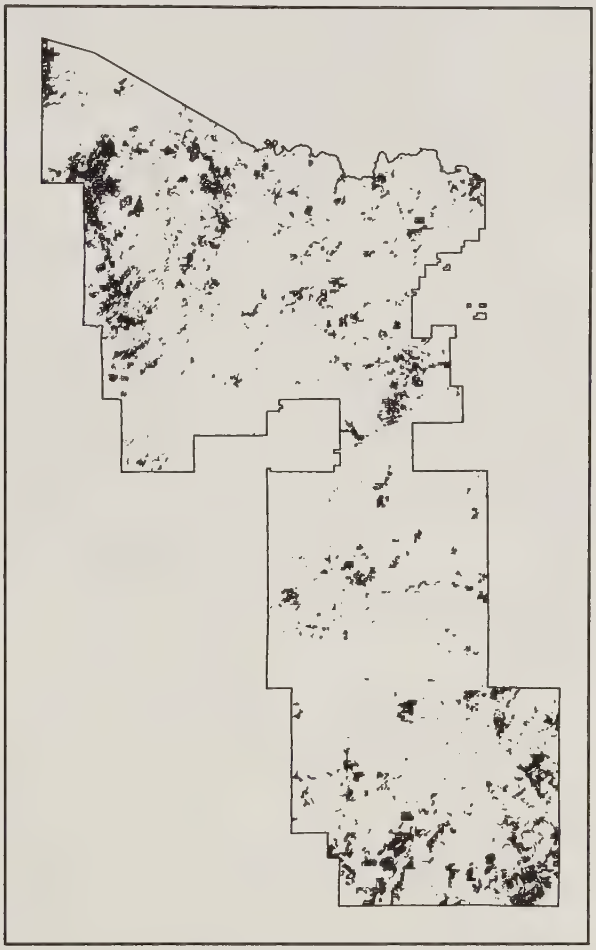

Figure 23. Location of the pine type on the Nicolet.

Forest Type Summary

- The overall health of red pine stands older than 20 years is excellent. However, red pine plantations less than 20 years old are being affected by competing vegetation that can reduce stand survival and growth. In addition, some competing vegetation, such as sweetfern, can create problems by serving as the alternate host for Saratoga spittlebug, historically a killer of young red pine on the Nicolet.

- Planting pine in frost pockets has led to significant tree mortality.

- Managing young red pine under or in the vicinity of large, overstory red pine can create conditions conducive to shoot blight fungi, especially on the northern half of the Forest. These fungi occur in periodic outbreaks when weather conditions are conducive.

- The age distribution for jack pine stands on the Nicolet indicates that most are relatively old, having originated in the 1930's. Increased mortality and top-kill should be expected in these stands, because jack pine stands rapidly deteriorate after age 50-60.

- Regenerating vigorous, young jack pine stands will require significant stand disturbance, either clearcutting or burning.

- White pine numbers are slowly increasing on the Nicolet, some management techniques could further increase the amount of white pine on the Forest despite localized blister rust, deer browsing, and white pine weevil concerns.

Jack Pine

The jack pine forest type is currently dominated by older stands. This is a concern because jack pine is a relatively short-lived tree. In addition, a 1992-94 outbreak of jack pine budworm left a number of trees with dead tops and poor vigor.

Jack pine is a fast-growing, short-lived, pioneer species that usually does not exceed 60 to 70 years of age. It typically invades areas where mineral soil has been exposed after a major disturbance. It usually grows in pure, even-aged stands or in mixtures with species such as northern pin oak and aspen. It is most prevalent on dry, nutrient-poor sites; on better sites it is easily outcompeted by other tree species. Because the Nicolet is dominated by mesic to wet sites, jack pine was not widespread on the Forest historically. However, jack pine was and still is prevalent on localized areas on the Forest that have sandy, dry soils. These areas are concentrated on the Eagle River and Lakewood Ranger Districts.

In northern Wisconsin, jack pine was widely planted during the 1930's and 1940's. Many of these plantations were established at very high densities (3- by 5-ft spacing) and never thinned. Consequently, today these stands support trees with small diameters and small crowns that are very prone to ice, snow, and wind damage. In addition, some of the planting stock used came from seed collections that were not local to northeastern Wisconsin. Further, some of the early plantations were established on sites ecologically inappropriate for jack pine. Many of these sites were extremely dry and, therefore more appropriate as barrens or prairies; or they were nutrient-rich, mesic sites that were better suited to more nutrient-demanding trees.

Age Class Distribution

On the Nicolet, most jack pine stands are currently 50-60 years old (Figure 24). Many of these originated as plantations in the mid-1930's and early 1940's.

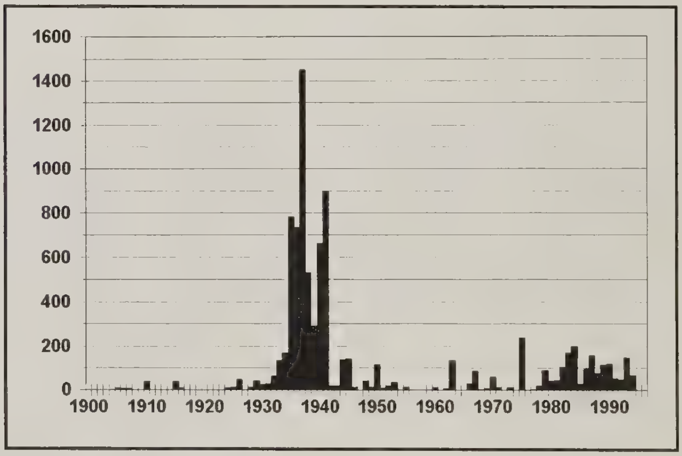

Figure 24. Year of origin of jack pine stands on the Nicolet.

Historical Disturbance Agents

Jack pine requires a major disturbance to naturally regenerate itself. Historically, crown fires were the key disturbance in jack pine stands. In the absence of fires, jack pine trees would have begun to decline and die at about 50-60 years and, would have been replaced by more shade tolerant trees. Fires eventually killed the shade tolerant trees, generally hardwoods, and once again created conditions conducive to jack pine regeneration. Several native insects and diseases, especially jack pine budworm, probably played a very active role in the decline and death of older trees. Budworm caterpillars weakened and killed trees by eating the needles; the weakened trees were then more easily attacked by bark beetles and root disease. Tree mortality caused fuel loads to build, thus increasing the likelihood of a significant fire. Fire favored the regeneration of jack pine, so despite being "pests," insects and diseases actually favored the long term maintenance of jack pine-dominated forests.

Snow, ice, and wind damage was probably common, especially in older, dense stands that had small crowns and small diameter stems. Broken tops and stems would have created material that would have attracted insects such as bark beetles that would have killed additional trees.

Recent Disturbance Agents

Today, harvesting activity is commonly used to create the necessary site disturbance for naturally regenerating jack pine stands. Because jack pine is very intolerant of shade, clearcutting creates the high light conditions optimal for jack pine regeneration. Fire is still a viable method of creating favorable regeneration conditions, though it is generally suppressed.

In the absence of clearcutting or fires, jack pine stands deteriorate and die in much the same way as they did in the past. Older stands are defoliated by jack pine budworm on a 5- to 10-year cycle which begins a period of stand decline that may last 10-20 years. Eventually, most jack pines die and are replaced by more shade tolerant trees. In some stands ice, snow, or wind damage can begin the decline process as well.

Future Disturbance Agents

Future disturbances affecting jack pine stands will likely be the same ones affecting the species now. Jack pine budworm will continue to produce outbreak populations across the region on a 5- to 10-year cycle. The severity of these outbreaks will vary greatly depending upon the age class distribution of jack pine stands in the area. If most stands are older than 50 years, mortality and stand decline will be common. However, if younger stands are prevalent, then budworm populations will probably not be as large and the impact not as severe. For younger stands to become established, a major disturbance agent will have to be active in the jack pine forest type. This agent could be intense crown fires or clearcut harvesting. In the absence of a major disturbance agent, most jack pine stands will convert to later successional species and jack pine will become less prevalent.

Major Insects and Pathogens

Armillaria root disease, caused by *Armillaria* spp., is ubiquitous in North American forests. The disease is caused by one of several species of fungi that can survive as a parasite on living tree tissue, most often roots, and on dead woody material in the soil. Armillaria root disease typically invades and kills trees that are already weakened. In jack pine, weakened trees are a result of old age, drought, or defoliation by an insect such as jack pine budworm. This disease often works slowly in older jack pine stands, killing a few trees annually. However, after 10-15 years, the impact may be significant in some stands.

Jack pine budworm, *Choristoneura pinus pinus*, is the most significant insect attacking jack pine (photo - Appendix III). It is native to Wisconsin forests and is considered one of the most regularly cyclic forest insects in North America, with an outbreak occurring every 5-10 years in northern Wisconsin. Each outbreak generally lasts 2-3 years. The level of defoliation that occurs during outbreaks varies in intensity. One major factor in determining intensity is the number of male flowers produced by jack pine because male flowers are the preferred food source for the young caterpillars. If flowers are abundant, the caterpillars have higher survival rates and produce more offspring. Old, mature jack pine stands often produce many male flowers and young stands produce few. Thus, older stands encourage the buildup of large budworm populations. Further, defoliation tends to be more intense in older stands, and the trees themselves undergo severe stress as a result of needle loss. Finally, older stands are generally less vigorous than younger stands, which results in outright tree mortality and invasion of the stressed trees by Armillaria root disease and bark beetles, leading to additional tree mortality.

The amount of tree mortality and top-kill after outbreaks has been variable historically, depending upon the intensity of the outbreak and the variability found within stands. An extensive study was conducted on the Hiawatha National Forest after the 1991-93 outbreak.[25] This study reported an average of 8-10 percent tree mortality and 17-20 percent top-kill 2 years after the outbreak had subsided. Mortality was significantly greater in stands older than 40 years.

Ips bark beetles, *Ips pini* and *Ips grandicollis*, are native bark beetles in Wisconsin that often attack jack pine. The beetles require weakened trees for breeding. In most cases, these beetles do not reach epidemic levels, although localized outbreaks can occur after periods of drought or defoliation. Older jack pine stands, especially those previously defoliated by jack pine budworm, are quite susceptible to bark beetle attack. Over a 5- to 10-year period the overall impact can be significant. Young jack pine are resistant to bark beetle attack.

Summary

Jack pine is a relatively short-lived tree vulnerable to several agents that can hasten tree death. Many of these agents, such as jack pine budworm, have evolved with jack pine over a long period of time. Tree mortality will become more common in stands as they grow older than 50 years. Jack pine also requires significant disturbance to regenerate vigorous, young stands. The following are the most important forest health concerns in jack pine forests:

- Stand age - stands older than 50 years will have increased levels of tree mortality. Trees older than 70 years of age will be very difficult to maintain.

- Major disturbance agent - vigorous regeneration will require a significant site disturbance. Establishing vigorous, young jack pine stands will require a commitment to either clearcutting or intense burning.

[25]McCullough, D.G.; Marshall, L.D.; Buss, L. 1995. Effects of stand age and site index on jack pine budworm damage in the Raco Plains area of Michigan. In: Volney, W.J.A.; Nealis, V.G.; Howse, G.M.; *et al.* eds. Jack pine budworm biology and management. Proceedings of the jack pine symposium. Information Report NOR-X-342: 1995 January 24-26: Winnipeg, MB: Canadian Forest Service, Northwest Region: 97-106.

Red Pine

Most red pine trees on the Nicolet are growing in plantations established during the 1930's and 1940's. Most of these plantations are today quite vigorous. Some concerns about regenerating young red pine exist at this time. Specifically, there is a history of problems from Saratoga spittlebug, Sirococcus shoot blight, and recurrent frost injury.

Red pine is a moderately long-lived tree that is largely confined to dry soils where it grows well and can successfully outcompete hardwoods when it is young. However, on very dry, sandy soils, it generally grows poorly. Red pine grows naturally in pure stands, though it more often occurs in mixtures with white pine, jack pine, northern pin oak, quaking aspen, red maple, and northern red oak. It is the most common plantation species in the Great Lakes Region and has been widely planted on the Nicolet, generally in pure plantations. Historically, red pine was a common tree in northern Wisconsin. Today, despite widespread planting, it is much less abundant than it was before the logging era.

Age Class Distribution

Most red pines stands on the Forest were established as plantations between 1933 and 1950 (Figure 25). The red pine planting program has continued since that time, but at a lower level. Few red pine stands of natural origin are present, though naturally occurring red pine trees are scattered throughout the Forest as components of other forest cover types.

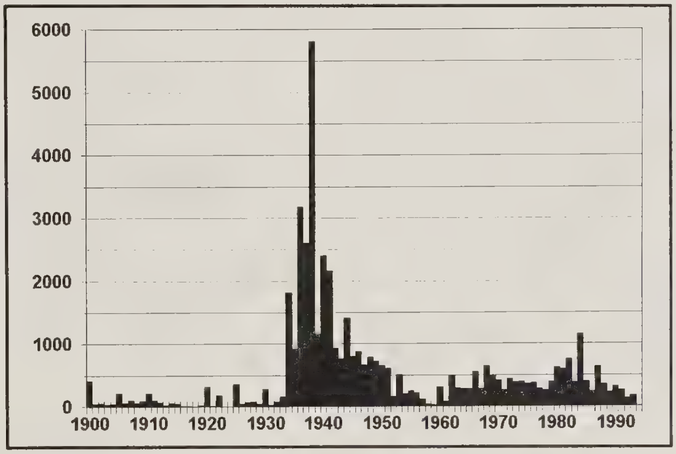

Figure 25. Year of origin of red pine stands on the Nicolet.

Historic Disturbance Agents

The primary disturbance agent in red pine-dominated stands in the past was probably fire. Young pine stands would have been susceptible to fire, but older red pine trees were quite resistant to most fires due to their thick bark.

Once red pine stands reached 15-20 years of age, they had few damaging agents other than fire. Before that age, they were probably affected by the same insect, pathogen, and abiotic problems (frost) that are discussed below under Recent Disturbance Agents. If young red pine trees became established in areas prone to these insects, pathogens, or recurrent frost, they very likely died or grew very poorly. Red pine trees are capable of life spans of 150-250 years. They would have eventually died from root diseases, wind damage or from bark beetle infestations.

Harvesting during the middle to late 1800's, along with the fires and land clearing that followed were all major disturbances that resulted in significantly fewer red pine trees.

Recent Disturbance Agents

During the 1930's and 1940's, red pine became the most widely planted tree in the Great Lakes Region. Red pine planting has continued on the Nicolet since the 1930's, though the current planting program is greatly reduced. Most of these older plantations are currently in excellent vigor, though some plantations had significant tree mortality during the establishment phase. The most serious problems were Saratoga spittlebug outbreaks, shoot blight outbreaks, and frost injury.

Saratoga spittlebug outbreaks have been most common in young red pine stands growing on dry, nutrient-poor sites. These sites often support an abundance of sweetfern, one of the alternate hosts for this spittlebug. Insecticides for direct control of spittlebugs and herbicides for control of alternate hosts were used on the Nicolet in the past. Today, these pesticide treatments are no longer used on Lake States national forests, although spittlebug populations continue to be a serious threat to newly established plantations.

On the Nicolet, red pine shoot blight may be caused by either Diplodia shoot blight or Sirococcus shoot blight. Two epidemics of Sirococcus shoot blight in 1972-76 and 1992-94, have been reported on the Forest. In the intervening years, Sirococcus shoot blight infections have been rare. A study conducted on the Northern Highlands State Forest reported 67 percent mortality of red pine growing under overstory red pine after the 1972-76 epidemic. These findings resulted in management recommendations that discouraged the development of multi-storied red pine stands[26]. Thirty-four red pine stands scattered across the Nicolet were surveyed for Sirococcus shoot blight in 1970; 11 of the 34 stands had shoot blight in them. A 1973 resurvey of 33 of the stands found that 8 of those previously infected stands plus 3 new stands had active shoot blight. Infected stands were concentrated in the northern half of the Forest. The report suggested that Sirococcus shoot blight should be a major concern only in red pine stands on the northern half of the Nicolet[27]. Diplodia shoot blight is a major contributor to shoot blight problems on the adjacent Northern Highlands State Forest. Diplodia has been observed on the Nicolet[28], though it has not been implicated in any large-scale epidemics.

Finally, planting red pine into frost pockets has resulted in extensive mortality of young red pine from repeated frost injury and from the increased incidence of Scleroderris canker. The Lake States strain of Scleroderris canker is present on the Nicolet and is much more prevalent in small depressions where frost is likely. A survey conducted between 1966 and 1970 on the Nicolet and surrounding areas found that Scleroderris canker was affecting trees, but only in localized plantations in depressions[29]. In these depressions, mortality could be quite severe, ranging from 15 to 32 percent.

Many red pine plantations on the Nicolet have developed into densely stocked stands. Trees in these stands tend to have small crowns and small diameter stems that are very prone to ice, snow, and wind damage. In addition, dense stands are more susceptible to bark beetle outbreaks during periods of drought. Thinning red pine stands between the ages of 20 and 30 years develops larger crowns and bigger diameters, which create trees that are more vigorous and less prone to ice, snow, and wind damage.

Mature trees have remained relatively free of major insect and pathogen problems, and fire suppression has reduced losses due to fire.

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[26] Ostry, M.E.; Nicholls, T.H.; Skilling, D.D. 1990. Biology and control of Sirococcus shoot blight on red pine. Research Paper NC-295. St. Paul, MN: USDA Forest Service, North Central Experiment Station. 11 p.

[27] O'Brien, J.T.; Anderson, B. 1974. 1973 resurvey for Sirococcus shoot blight of red pine on the Nicolet National Forest. Report No. S-74-1. St. Paul, MN: USDA Forest Service, Northeastern Area State & Private Forestry, Forest Pest Management. 4 p.

[28] Haugen, L.; O'Brien, J.G. 1993. Evaluation of cause and incidence of red pine shoot blights on the Chequamegon, Ottawa and Nicolet National Forests in 1993. Internal Report. St. Paul, MN: USDA Forest Service, Northeastern Area State & Private Forestry, Forest Health Protection. [Not Paged].

[29] O'Brien, J.T. 1972. Evaluation of Scleroderris canker in red pine plantations of the Lake States. Report No. S-72-1. St. Paul, MN: USDA Forest Service, Northeastern Area State & Private Forestry, Forest Pest Management. 8 p.

Future Disturbance Agents

Red pine stands past the age of 15 years should remain relatively free of pest problems. However, some current management practices threaten the future establishment of red pine stands. First, the inability to use herbicides for control of competing vegetation makes the establishment of red pine difficult on some sites, especially sites that are nutrient-rich. The inability to control competing vegetation with herbicides may force land managers to consider planting on drier, more nutrient-poor sites that have less competition. However, these sites are prone to having an abundance of sweetfern and are likely to undergo many periods of drought stress. The presence of sweetfern significantly increases the risk from Saratoga spittlebug, and drought increases the likelihood of Diplodia incidence. Next, multi-storied red pine stands established for aesthetic reasons or as an attempt to obtain natural regeneration of red pine are conducive to both Sirococcus and Diplodia shoot blights. Past history of shoot blight on the Forest indicates that managing red pine in multi-storied stands should be avoided, especially on the northern half of the Forest.

Major Insects and Pathogens

Saratoga spittlebug, *Aphrophora saratogensis*, is a small sucking insect that feeds as an adult on both red and jack pine twigs and branches. The adult spittlebug injures twigs and branches by puncturing the bark with its straw-like mouthparts and disrupting the flow of water and nutrients. Trees most susceptible to attack are those less than 16 feet tall growing in areas with abundant sweetfern. The immature stage of this insect requires sweetfern or one of several other woody or herbaceous plants (willow, blackberry) to complete its life cycle. Generally, sweetfern must occupy 35-40 percent of the ground to produce spittlebug populations capable of inflicting moderate to heavy damage.[30] This insect has caused considerable damage to red pine plantations on the Nicolet over the years. A 1981 survey of 162 young red pine plantations on the Forest reported that 7 plantations were completely destroyed and an additional 20 stands were severely threatened by spittlebug.[31] On the Nicolet, between 1945 and 1976, a total of 54,604 acres were treated with insecticides for spittlebug control. Most of that spraying occurred during the 1950's, using the insecticide DDT. In the 1970's, only 40 acres were treated, in this case using the insecticide malathion.[32] In the 1980's, control was accomplished using herbicides to kill the alternate host, sweetfern. This method controlled the spittlebug and served to release red pine from competition. At this time, herbicides are no longer considered for use on national forests in the Lake States.

Red pine shoot blight is caused by the fungus *Sirococcus conigenus*. The fungus infects the succulent new growth of red pine in May and June, resulting in dead needles and drooping or curled shoots later in the summer (photo - Appendix III). Tiny black fruiting bodies form at the base of dead needles and on dead shoots. Rainy mild weather during the spring favors disease development. This disease was first reported on the Nicolet in 1959 and was at epidemic levels from 1972 to 1976 and from 1992 to 1994. In some areas, it caused significant tree mortality or deformation. Heavily affected stands were concentrated on the northern half of the Forest. Further, most damage was confined to smaller red pine growing under or adjacent to infected overstory red pine. Cultural control include these steps:

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[30] Wilson, L. 1987. Saratoga spittlebug - its ecology and management. Agricultural Handbook No. 657. Washington, DC: US Department of Agriculture. 56 p.

[31] Haynes, E. 1982. Appraisal of current and potential injury by the Saratoga spittlebug on the Nicolet Forest - 1981. Administrative Report 82-1. St. Paul, MN: USDA Forest Service, Northeastern Area State & Private Forestry. 13 p.

[32] Fowler, R.; Wilson, L.; Paananen, D. 1986. Insect suppression in Eastern Region National Forests: 1930-1980. General Technical Report NC-103. St. Paul, MN: North Central Forest Experiment Station. 56 p.

- Avoid the development of two-story or uneven-aged red pine stands.

- Remove infected trees, if practical.

- Avoid planting red pine on high hazard sites which include small forest openings, shady sites, and north- or west-facing slopes.

Diplodia shoot blight and canker is caused by the fungus *Sphaeropsis sapinea*. Like red pine shoot blight, this fungus infects elongating shoots. Fruiting structures develop on killed needles, dead twigs, and cones the same year or the following spring. In addition, the fungus may cause cankers (dead areas on branches or the main stem) or collar rot. Diplodia is particularly damaging in conjunction with stressors such as drought, frost, or hail damage. To avoid Diplodia-related problems, red pine should not be planted on very dry, nutrient-poor sites or under mature red or jack pine.

Scleroderris canker, caused by the fungus *Gremmeniella abietina*, is thought to have been distributed throughout Lake States red pine plantations on infected nursery stock in the late 1950's and the 1960's. In the 1980's, there was great concern over the potential for extensive damage to red pine from the more aggressive European strain of the pathogen, but this strain has not spread to the Lake States. Currently, the Lake States strain of Scleroderris canker primarily occurs in frost pockets and on lower branches, and does not cause significant impacts on the Nicolet.

Summary

Red pine is a moderately long-lived tree. On the Nicolet, the vast majority of red pine trees have been established in plantations, many between 1930 and 1950. These trees are therefore relatively young and in good overall health. No serious native or exotic insects or pathogens currently threaten the red pine resource. Establishing new red pine stands, either as plantations or via natural regeneration, may be difficult unless certain management practices are adhered to. The following are the most important forest health concerns in red pine forests:

- Establishment of new stands - young red pine stands can be prone to several serious problems related to insects, pathogens, frost, and competition. The establishment of healthy, young stands will require good site selection to avoid many of these problems, especially if herbicides are not available for stand establishment and release. Frost pockets and areas with an abundance of sweetfern should be avoided in planting programs.

- Thinning of plantations is necessary to develop larger crowns and vigorous trees. Dense plantations that have not been thinned will have trees with small crowns that are prone to wind and ice damage. In addition, these trees are prone to bark beetle outbreaks during drought.

- Regenerating red pine under existing red pine overstories may lead to significant mortality during shoot blight outbreaks, especially on the northern half of the Nicolet.

White Pine

The white pine resource is slowly increasing its presence on the Forest. Impediments to further increases include competing vegetation, deer browsing, and, in some locations, blister rust. All of these impediments can be overcome by following certain management practices.

White pine is a long-lived tree commonly reaching 160-220 years of age, though individual trees can easily live twice that long. It grows on nearly all the soils found on the Nicolet, but generally competes best on well-drained sandy soils of low to medium site quality. These soils permit good growth of white pine but not of competing hardwoods. White pine can grow very well on nutrient-rich, mesic sites, but it can have a difficult time becoming established there due to strong competition from hardwoods such as sugar maple. White pine can be found in relatively pure stands, but more commonly it is found as a component of other forest stands along with red pine, hemlock, and oak. Because of its long life span, hemlock can be found in late-successional forests. However, in these stands, it will eventually be replaced by more shade tolerant trees such as sugar maple and hemlock. White pine regeneration is favored by site disturbance that provides a good seed bed and eliminates competing vegetation.

Age Class Distribution

Most white pine stands on the Nicolet range from 60 to 100 years of age (Figure 26). However, a significant number of younger trees are present in the understory of many other forest types. White pine's ability to regenerate and grow in moderate shade allows it to establish itself in understories. Eventually, much of this young white pine should develop into overstory trees and increase the presence of white pine on the Forest. The most recent Forest-wide inventory shows an increase in the number of white pine on the Nicolet between 1983 and 1996.[33]

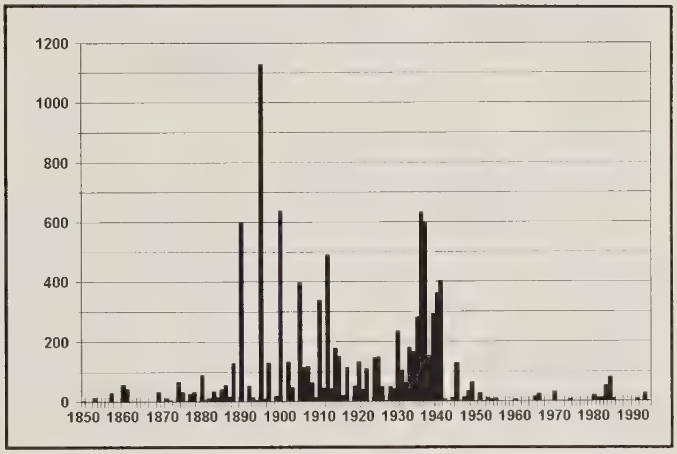

Figure 26. Year of origin of white pine stands on the Nicolet.

Historical Disturbance Agents

Fire and wind probably played very significant roles in providing the disturbance necessary for white pine regeneration. As long as regeneration occurred, even sporadically, white pine was maintained in the forest due to its long life span. Historically, it had no major insect or disease problems. In most cases, trees would have died at old ages, 160-220 years, from root disease, bark beetle attacks, and lightning strikes. Many trees, however, survived well past 250 years. Wind storms would have occasionally killed large areas of white pine. White pine weevil was undoubtedly present and very active in any young, open-grown white pine. However, this insect is not a tree killer and its effect on the overall forest would have been minimal. The development of white pine in understories or in dense young stands created after fires or windstorms would have discouraged white pine weevil.

[33] Forest Inventory and Analysis, USDA Forest Service, Nicolet 1996 data.

Between 1850 and 1900, logging had a major impact on white pine. Further, the widespread slash fires and clearing of land for agriculture in the area after logging killed much of the existing regeneration and many of the remaining seed trees.

Blister rust, an exotic disease, moved into Wisconsin around 1916. This disease limits the reproduction of white pine in some areas by killing young trees.

Recent Disturbance Agents

White-tailed deer populations are much greater in northern Wisconsin today than they were before the logging era. Deer can cause substantial damage to young white pine. Deer browsing was reported on 43 percent of all white pine seedlings surveyed in 18 plantations established on the Nicolet between 1983 and 1988.[34] This same survey looked at blister rust incidence in these plantations. Eleven of the 18 plantations had rust present, and on average about 7 percent of the trees were infected. White pine weevil is also present, especially on open-grown trees, 5 to 20 feet in height.

Today, white pine is reinvading many of the drier, sandier sites on the Nicolet. In these areas, it can regenerate under an existing canopy of aspen, oak, red pine, or jack pine. Competition from brush and northern hardwoods is not a concern on these drier sites. On the more nutrient-rich sites, white pine regeneration is less common, probably because of intense competition. White pine grows slowly for the first 3-5 years and can be outcompeted by hardwood trees and shrubs. The suppression of fires has eliminated one disturbance agent that historically provided an opportunity for white pine to establish itself on the more nutrient-rich sites. Further, herbicides, which could be used for pine release, are not used on the Forest.

Future Disturbance Agents

On most of the Nicolet, white pine could be much more prevalent if efforts were made to establish regeneration and to release existing regeneration from overhead competition. In most cases, this would require significant stand disturbance to improve seed bed conditions and to set back competition. Planting may be necessary in many cases because of a lack of seed sources in some areas. Blister rust may be very important in localized areas, especially along lakeshores, around swamps, and at the bases of hills. These areas tend to pool cool moist air and thereby encourage the incidence of blister rust. Future white pine stand establishment should consider the microclimate of all potential white pine stands. An emphasis on establishing a high density of young white pine and on pruning lower branches to prevent blister rust infections from starting, would increase the ability of white pine to develop on many sites. Overall, blister rust should not be viewed as a limiting factor in the management of white pine. The use of certain management techniques should allow white pine to grow in most areas despite the presence of blister rust.

High deer populations could also cause localized regeneration failures, especially in areas where deer congregate such as winter deeryards.

White pine weevil will attack trees. However, serious deformity will only occur when trees are open-grown at low stand densities. Well-stocked stands, even if open-grown, will in most cases develop into well-formed trees despite white pine weevil.

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[34] Mielke, M.E.; Charette, D.A.; O'Brien, J.G.; Haugen, D.E. 1990. 1990 Biological evaluation of white pine plantations on the Nicolet, Chequamegon and Ottawa National Forests. St. Paul, MN: USDA Forest Service, Northeastern Area State and Private Forestry, 8 p.

Gypsy moth will feed on understory white pine, especially trees that are growing under a canopy of oak or aspen. Complete defoliation of small trees can result in tree death, and gypsy moth may kill or severely injure pockets of young understory white pine. However, it may also benefit understory white pine by killing overstory trees and thereby releasing white pine from overhead shade.

Major Insects and Pathogens

Blister rust is a disease caused by the exotic fungus, *Cronartium ribicola* (photo - Appendix III). This Asian fungus was introduced into North America via Europe around the turn of the 20th century. Blister rust does not prevent the growing of white pine in northern Wisconsin, but it does make it more difficult, especially in certain localized areas that are very prone to the fungus.

Blister rust requires two different host plants to complete its life cycle. One host is white pine, the other is a small shrub called gooseberry (other names are *Ribes* and currants). During the summer the fungus grows on gooseberry leaves. In the late summer and fall, the fungus growing on the gooseberry leaves produces spores that infect white pine. These spores are moved by air currents. Sunlight, heat, and lack of moisture can kill the spores as they disperse in the wind. The spores must land on a needle to infect a white pine. Also, spores require moisture to be present on the needles for 48 hours and the temperature to be less than 68 degrees during that time. If those conditions exist, infection occurs and the fungus begins to grow slowly through the needle into the branch and eventually (several years later) into the main stem. Once in the main stem, the fungus can grow around the tree, killing it above the point of infection. In the spring, another spore stage is produced on white pine that reinfects the gooseberry leaves and continues the cycle.

Understanding the disease cycle provides some management insights:

- Cool, moist conditions in the late summer and fall are very conducive to blister rust, and blister rust is prevalent wherever these conditions predominate. Local areas that collect cool air and moisture encourage growth of the fungus, making blister rust more likely in places such as at the bases of slopes, in small openings, and along lakeshores.

- White pine trees under existing forest canopies have less dew formation than open-grown trees. Therefore, growing young white pine under an existing overstory can reduce the incidence of blister rust.

- Infection of pine occurs through needles. And, because moisture and temperature conditions are cooler near the ground, the vast majority (90 percent) of rust infections occur in the lower parts of trees. Therefore, pruning to remove needle-bearing branches in the lower portions of young trees can significantly reduce the incidence of blister rust.

- The spore stage produced on gooseberry is required to infect white pine. Therefore, as a general rule, the more abundant gooseberry is and the closer it is to white pine, the more likely the pine will be infected. Certain habitat types in northeast Wisconsin have been identified where gooseberry is less common and the potential for white pine reproduction and growth is excellent.[35] These types include Pinus/Maianthemum- Vaccinium and Acer/Vaccinium-Viburnum. The identification of these sites as good areas in which to grow and manage white pine may reduce the overall effect of blister rust.

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[35] Kotar, J.; Kovach, J.A.; Locey, C.T. 1988. Field guide to forest habitat types of northern Wisconsin. Madison, WI: University of Wisconsin, Department of Forestry: Wisconsin Department of Natural Resources.

Blister rust incidence is lower on the southern end of the Nicolet. On the neighboring Menominee Indian Reservation, blister rust levels are very low. Therefore, regenerating and managing white pine on the Lakewood Ranger District, especially on the habitat types mentioned above should avoid severe blister rust problems.

Finally, some mortality from blister rust should be expected and can be compensated for by managing young white pine stands at high densities.

White pine weevil, *Pissodes strobi*, is a native insect that attacks and kills the terminal shoot of white pines (photo - Appendix III). Weevil attacks do not kill trees, but can result in trees with crooked stems or trees that form multiple stems. The value of wood for wood products from these trees can be significantly reduced after attacks. However, many young pines are attacked by white pine weevils and recover their straight form with no great loss of value. Trees in dense young stands generally straighten quickly and do not develop large heavy branches at the point of attack. In contrast, open-grown trees that are widely spaced generally develop into crooked or multi-stemmed trees with large branches. Therefore, managing young white pine stands at high stand densities reduces stem deformity. In addition, weevil attacks can be avoided by growing young white pine in moderate levels of shade. However, at some point, overhead release becomes necessary because shade, even at moderate levels, reduces white pine growth rates.

Summary

White pine is a long-lived tree species that once established in the overstory should maintain itself for a long period of time. However, many trees begin to die from various causes at about the age of 160-220 years. The following are the most important forest health concerns for white pine:

- Establishment of regeneration - the lack of fires and the inability to use herbicides to prepare seed beds and to release white pine seedlings will limit the establishment of white pine regeneration, especially on more nutrient-rich sites.

- Blister rust - this disease will cause difficulties in regenerating white pine in areas that generally are very conducive to the disease, such as along lakeshores, around swamps, and in small openings.

- Deer populations - white pine can be heavily browsed by white-tailed deer. As long as deer populations are maintained at high levels, browsing will damage or kill young white pine in many areas.

Composition

For this report, we are considering white spruce and balsam fir as the predominant species in the spruce-fir type. Although many other species occur in this type, they are discussed elsewhere in this report.

Importance

On the Nicolet, the spruce-fir type occupies more than 33,000 acres and makes up approximately 5 percent of the Forest (Figure 27).

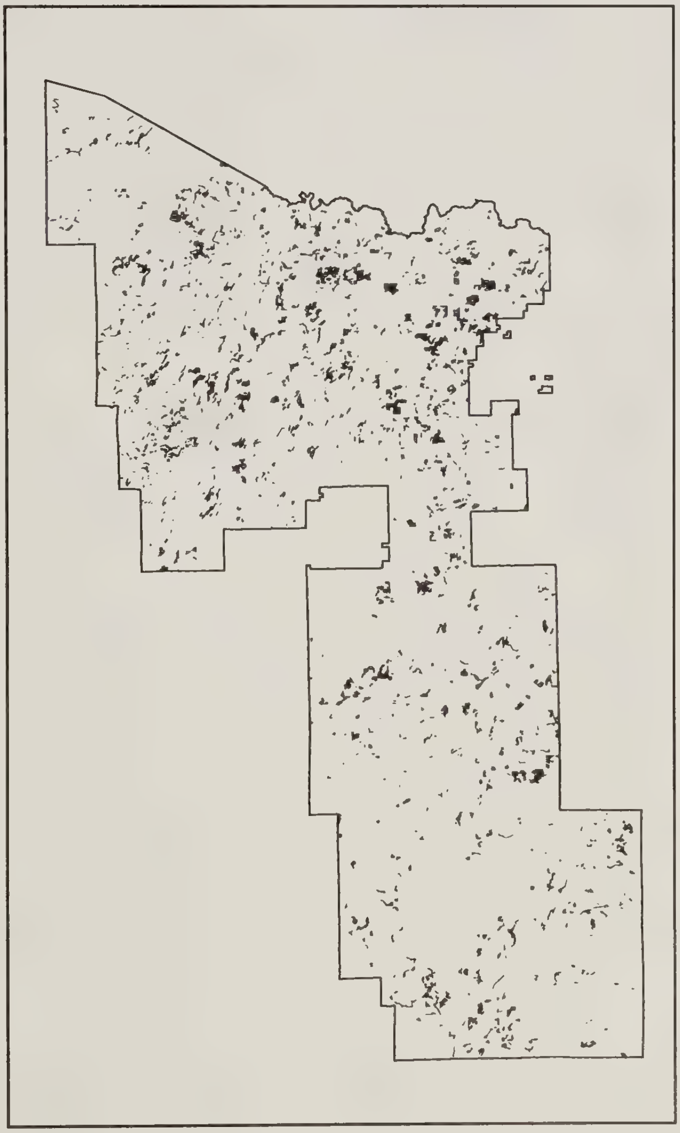

Figure 27. Location of the spruce-fir forest type on the Nicolet.

Forest Type Summary

- Balsam fir stands regularly support outbreaks of the spruce budworm; older stands are more prone to outbreaks and sustain greater mortality than younger stands. An outbreak may last 10- 15 years, and in most cases widespread mortality of balsam fir will occur. Harvesting at shorter rotation ages and maintaining a diversity of age classes between stands may help reduce losses.

- An overall increase in the presence of balsam fir across the Nicolet could encourage more frequent spruce budworm outbreaks in the area. Management practices can either encourage or discourage balsam fir. As an example, the exclusion of fire encourages the expansion of balsam fir.

- Spruce budworm also feeds on white spruce. However, following past outbreaks, mortality of white spruce has been less than that of balsam fir. Therefore, encouraging white spruce over balsam fir may reduce the intensity of future budworm outbreaks.

- There is some evidence that plantation management of white spruce has exacerbated pest problems related to both spruce budworm and possibly needlecast diseases. Establishing pure, even-aged blocks of one tree species can be inherently risky from an insect and disease standpoint. This may be especially true for a tree species that does not occur naturally in relatively pure stands.

Balsam Fir

Spruce budworm has a long history of prolonged outbreaks in the Great Lakes area that often result in widespread mortality of older balsam fir. The most recent outbreak occurred between 1972 and 1981, killing large numbers of the older balsam fir on the Nicolet. Today, a younger balsam fir component is established and replacing the trees lost during the 1970's and 1980's.

Balsam fir is a shade tolerant conifer that grows on a wide range of sites. In the northern Lake States, it is most common on cool, wet-mesic locations. Balsam fir can dominate stands, though it is also commonly found associated with white spruce, northern white-cedar, black spruce, and tamarack on wetter sites, and with red maple, sugar maple, white pine, red pine, aspen, and paper birch on upland sites. It is a short-lived tree that rarely survives longer than 80-100 years in northern Wisconsin, partly because of infrequent, yet devastating outbreaks of the spruce budworm. These outbreaks can cause widespread mortality of older trees, often within a 5-year period. Established seedlings, however, are not killed during budworm outbreaks, and the death of the overstory fir allows small trees to develop into a new balsam fir-dominated forest.

Age Class Distribution

Due to the widespread mortality of balsam fir that occurred in the 1980's, most balsam fir trees on the Forest are relatively young.

Historical Disturbance Agents

Spruce budworm is a native caterpillar that, despite its name, prefers balsam fir over spruce, though it readily feeds on both species. Spruce budworm outbreaks have been a part of the spruce-fir forest type for a long time. In the past, these outbreaks occurred at irregular intervals over large regional areas and generally continued for as long as 15 years, resulting in the death of most mature balsam fir in the forest. The death of the mature overstory trees allowed young balsam fir in these stands to be released and a new balsam fir forest was created. Therefore, outbreaks apparently act as a cycling mechanism that allows advance fir regeneration to succeed into the overstory.

Windthrow was also probably quite common because balsam fir has a shallow root system and is easily uprooted. In addition, decay is quite common in older balsam fir and would have increased the likelihood of wind damage. Balsam fir is very susceptible to damage from fire and even light ground fires would have killed old and young trees. The advent of fire suppression early in this century very likely led to an increase in the presence of balsam fir on the Nicolet.

Recent Disturbance Agents

In 1972, spruce budworm defoliated 300 acres on the Eagle River Ranger District of the Nicolet. The area of defoliation expanded to 600 acres in 1973, 10,000 acres in 1974, and 43,600 acres in 1975. This outbreak peaked in Wisconsin in 1980 when 180,000 acres were defoliated statewide (Figure 28), and very little defoliation was reported in 1981 and 1982. Mortality of mature balsam fir in northeastern Wisconsin was widespread by the early 1980's. No reliable estimates for the numbers of trees killed on the Nicolet during that time period are available. However, mortality surveys were made on the neighboring Watersmeet Ranger District on the Ottawa National Forest in 1981[36]. There, cumulative balsam fir mortality was 44 percent, which represented approximately 31 percent of the spruce-fir basal area in all spruce-fir stands. Top-kill was present on an additional 27 percent of the remaining live trees. It is not unusual for trees to continue to die for several years after an outbreak, and additional mortality probably occurred past this 1981 survey.

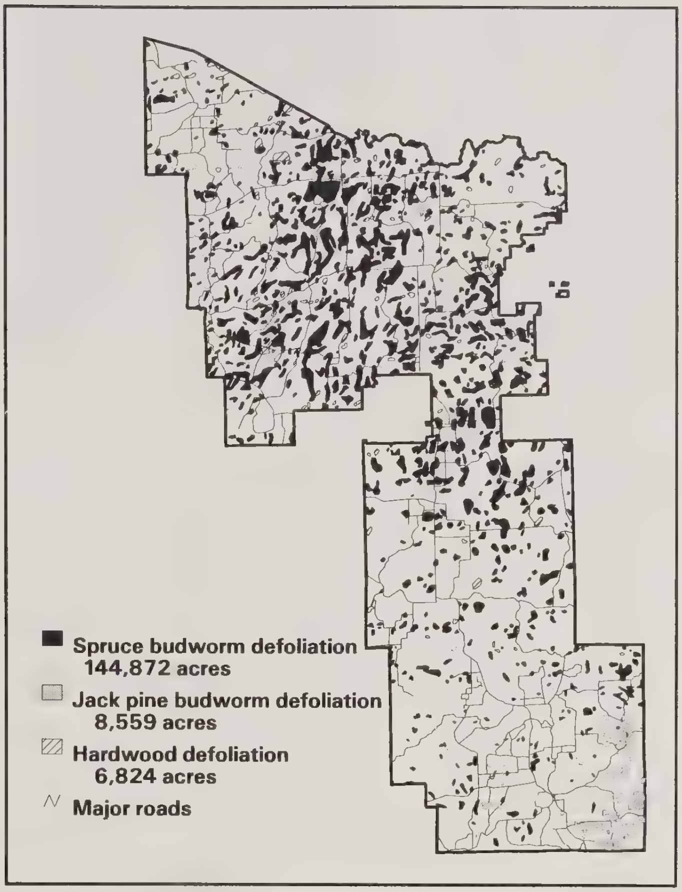

Figure 28. Aerial survey results of defoliation on the Nicolet in 1980 when spruce budworm activity was at its peak.

Additional spruce budworm outbreaks have not been reported on the Nicolet, though some spruce budworm activity was reported between 1995 and 1997 in scattered locations in northern Wisconsin and the western Upper Peninsula. Young balsam fir established before the latest outbreak are thriving on the Nicolet. The most recent Forest-wide inventory shows the number of balsam fir trees on the Forest increasing significantly between the 1983 and 1996, with the biggest increase in trees between 1 and 2.9 inches in diameter (small trees)[37].

Future Disturbance Agents

On the Nicolet, spruce budworm will continue to be the major disturbance affecting balsam fir. Regional outbreaks will occur at some point in the future. The likelihood of an outbreak increases as the age and size of the balsam fir resource increase. During the next outbreak, large-scale mortality of mature balsam fir should be expected within 5-7 years of the initiation of defoliation. The likelihood and the extent of future outbreaks increase as the amount of balsam fir increases in northeastern Wisconsin. Fire suppression is one reason that balsam fir is likely to increase over this area.

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[36] Lynch, A.M.; Witter, J.A. 1983. Spruce budworm impact in 1981 on 25 spruce-fir stands in the Bessemer, Watersmeet, Ontonagon, and Bergland Districts of the Ottawa National Forest. Technical Report 83-4. Ann Arbor, MI: University of Michigan: Michigan Cooperative Forest Pest Management Program. 49 p.

[37] Forest Inventory and Analysis, USDA Forest Service, Nicolet 1996 data.

Spruce Budworm - *Choristoneura fumiferana*, is the single most damaging insect of balsam fir (photo - Appendix III). In the Lake States, past outbreaks have resulted in 40 to 100 percent mortality of host trees in mature balsam fir stands. Mortality is slightly less in younger stands. Outbreaks typically last for 7-15 years, ending when most host trees have died. Significant tree mortality normally does not begin until year 4-6 of the outbreak. Outbreaks are infrequent; there may be 40-60 years between outbreak periods. Budworm outbreaks disrupt the wood-producing capacity of forests, but in terms of overall ecological stability, outbreaks apparently act as a cycling mechanism that allows advance regeneration to succeed the fir and spruce overstory.

Spruce budworm caterpillars feed in the early spring. The caterpillars feed initially by mining needles and buds and then later by feeding directly on needles. Eventually, most of the mature fir and some of the white spruce dies, resulting in a large fuel load in most stands. Historically, fires have followed many budworm outbreaks. Fires readily kill the advanced spruce and fir regeneration and create early successional forests with only a small component of spruce-fir. In the absence of fire, the abundant spruce and fir regeneration quickly creates a new spruce-fir forest. Thirty to forty years later, these forests are again prime habitat for spruce budworm.

Literally hundreds of publications have been written on the biology, ecology, impact, and management of spruce budworm. Despite this, we still have a poor understanding of what initiates outbreaks. Further, we have made little, if any, headway in reducing the likelihood of future outbreaks or in reducing the likely impact of those outbreaks. In fact, many of our current management practices, especially fire suppression, encourage rather than discourage spruce budworm by encouraging more balsam fir.

We do have a good understanding of the tree's response to repeated defoliation which is outlined below.[38]

Succession of events associated with a spruce budworm outbreak on balsam fir.

Number of Years of Severe Defoliation	Impact
1	Growth decreases in the upper 1/3 of the tree's stem.
2-3	Small roots begin to die. Height growth ceases. Some tree tops begin to die.
4-6	Many overstory and overmature trees die. Tree growth nearly ceases on remaining live trees.
7-15	Budworm populations begin to decline. More trees die. Some seedlings and saplings die.

Silvicultural recommendations stress shortening the rotation age of balsam fir to 50 years or less and managing to discourage balsam fir. Large blocks of susceptible mature spruce-fir forest should be avoided.

[38] Montgomery, B.A.; Witter, J.A.; Simmons, G.A.; Lynch, A.M. 1983. Spruce budworm information leaflets for the Lake States II: The effects of spruce budworm outbreaks on trees and stands. Leaflet 83-8. East Lansing, MI: Michigan Cooperative Forest Pest Management Program.

Armillaria root disease is the most frequently encountered root disease in balsam fir. Sandy soils favor development of this disease. Armillaria root rot usually attacks stressed hosts, often killing trees predisposed by such disturbances as a spruce budworm outbreak or drought.

Red heart rot is caused by the fungus *Phellinus pini*. The fungus causes a very slow-growing white pocket rot and is usually confined to central heartwood portions of most trees. *Phellinus pini* is probably responsible for most central stem decay of conifers in the Lake States. It is assumed that the fungus infects through wounds, perhaps when trees are quite young, but decay is usually pronounced only in older trees that have a large cylinder of heartwood.

Summary

Spruce budworm has a long history of prolonged outbreaks in the Great Lakes area that often result in widespread mortality and top-kill of older balsam fir. Although budworm outbreaks disrupt the wood-producing capacity of forests, they apparently act as a cycling mechanism that allows advance regeneration to succeed the fir and spruce overstory. The following are the most important tree health concerns for balsam fir:

- Age class distribution - older stands seem more prone to generating outbreaks of the spruce budworm, and often have greater mortality than younger stands.
- Spruce budworm outbreaks - regional outbreaks should be expected in the Upper Great Lakes every 40-60 years. An outbreak may last 10-15 years, and in most cases widespread tree mortality will occur.

White Spruce

The white spruce trees on the Nicolet are generally in good health. White spruce has been damaged during outbreaks of the spruce budworm, though it survives defoliation well. Spruce budworm could become a more serious problem for white spruce if management objectives include maintaining a high population of balsam fir.

White spruce is considered a long-lived tree that is intermediate in its tolerance to shade. It can persist in an understory for many years, and because of its long life span and ability to respond to release, it eventually can become a long-term component of the overstory. White spruce has the ability to grow on a wide variety of sites, but for good growth, it needs a higher nutrient level than other native conifers. It is primarily a boreal species, and the southern limit of its natural range is found in central Wisconsin. In the Lake States it rarely makes up more than 30 percent of natural stands. Despite this, white spruce has been extensively planted in plantations in the region since the 1930's. Some of these plantations have had health problems not normally encountered in natural stands.

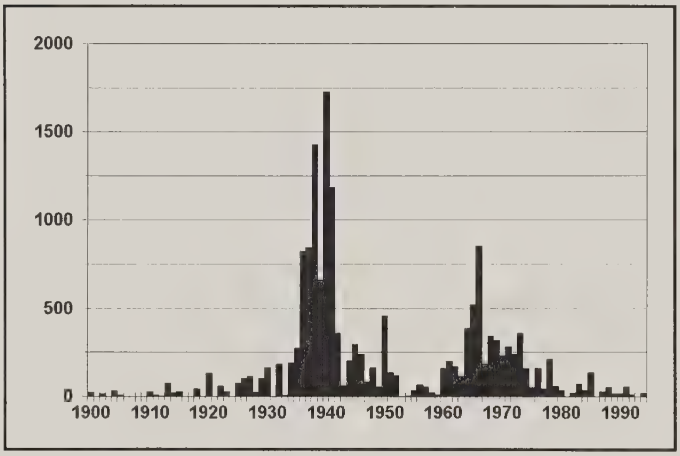

Figure 29. Year of origin of white spruce/balsam fir/aspen stands on the Nicolet.

Age Class Distribution

Most of the white spruce stands on the Nicolet were established between 1935 and 1965 (Figure 29). Stands older than 70 years currently are rare. Few young stands have been established recently. However, many small white spruce trees are present, mostly as natural regeneration. Much of this regeneration, as well as many larger trees, is scattered in other forest types.

Historical Disturbance Agents

In the past, spruce budworm would have occasionally occurred at outbreak levels across the region. However, white spruce is generally much more tolerant of defoliation than is balsam fir, and most white spruce probably survived spruce budworm outbreaks. Because white spruce probably occurred scattered in other forest types, the incidence of diseases, particularly needlecast diseases, would have been quite low.

Fire was probably an important disturbance agent of spruce forests. The frequency or interval between fires was the most important factor because repeated burns would have discouraged spruce by killing regeneration as well as potential seed trees. Longer intervals were more favorable to the existence of white spruce. Mature trees are highly flammable and their persistent branches permit even small ground fires to readily escalate into stand-replacing crown fires. Although mature trees are vulnerable to fire and readily killed, fire would have created conditions conducive to seedling establishment.

White spruce, especially older trees, would have been susceptible to windthrow, especially on wetter or very rocky sites where white spruce develops a shallow root system. Trees older than 200 years were likely to have had large amounts of trunk and root decay. In addition, older trees were more likely to sustain outbreaks of bark beetles, especially one called the spruce beetle, *Dendroctonus rufipennis*. These outbreaks may have occasionally killed large numbers of older white spruce in the area.

Recent Disturbance Agents

In recent times, spruce budworm has become a more important disturbance agent in the area, because northeastern Wisconsin has more white spruce and balsam fir today than it had historically. Several large budworm outbreaks have been reported since the early 20th century. The most recent spruce budworm outbreak on the Nicolet occurred between 1973 and 1981. Despite the severity of this outbreak, few white spruce trees actually died. A 1978 survey of white spruce plantations on the Nicolet reported widespread defoliation, but little tree mortality[39]. Trees that died were generally smaller ones that were suppressed or in intermediate crown positions.

Some plantation white spruce trees between the ages of 30 and 60 years in the Lake States have generally declined during the past 10-15 years. Symptoms include reduced growth rates and severe needle loss in the lower two-thirds of affected trees. At this time no plantations on the Nicolet have been observed with this decline, though plantations on the Chequamegon National Forest do exhibit these symptoms. The reason for the decline in these plantations is still unclear. It may relate to needlecast diseases such as *Rhizosphaera kalkhoffii*, to weather events such as periods of drought, or to site-related factors such as soil type. The Nicolet is on the southern edge of the natural white spruce range, and these problems may be manifestations of the poorly understood factors that prevent white spruce from existing farther to the south. Whenever any tree species is pushed beyond its natural range, increased health problems should be expected.

There is some evidence that plantation management of white spruce has exacerbated problems related to both spruce budworm and the decline problem mentioned above. Establishing pure, even-aged blocks of one tree species can be inherently risky from an insect and disease standpoint. This may be especially true for a tree species that does not occur naturally in relatively pure stands.

Young white spruce stands, especially those established in open areas, low areas, or along forest edges can be very susceptible to spring frost injury. Frost kills the new growth on trees, and repeated frost injury can stunt trees significantly.

Future Disturbance Agents

Spruce budworm will continue to be a concern in the management of white spruce. Occasional outbreaks will result in growth loss and some scattered mortality, especially in suppressed trees. Spruce budworm could become a more serious problem if white spruce and balsam fir increase their presence significantly in the area. An increase in fir especially could encourage more frequent spruce budworm outbreaks in the area.

The long-term significance of decline problems in some spruce plantations is unknown. Again, the decline scenario discussed above has not been observed on the Nicolet. However, the problem may be avoided by selecting ecologically appropriate sites for any future white spruce plantings. In addition, establishing white spruce in mixed stands in contrast to pure plantations may be beneficial in avoiding many insect- or disease-related problems, though mixtures with balsam fir should be avoided.

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[39] Whyte, L. 1979. Spruce budworm damage in spruce plantations on the Nicolet National Forest, 1978. Evaluation Report NA-FR-11. Broomall, PA: USDA Forest Service, Northeastern Area State & Private Forestry. 7 p.

Major Insects and Pathogens

Spruce budworm, *Choristoneura fumiferana*, is the single most damaging insect in the spruce- fir forest type. It is discussed in detail within the balsam fir section of this forest type.

Rhizosphaera needle cast, *Rhizosphaera kalkhoffii*, is a fungus that causes premature death of needles on white spruce. Generally, damage in natural forests is minimal, but significant defoliation can occur on landscape and plantation trees. Infection usually begins in needles on low branches. If favorable conditions exist for the pathogen, it generally spreads upward and outward in the tree. Infected needles die and are cast (drop). Spruce trees with dead needles or defoliation at the bottom of the tree are characteristic of the disease.

Summary

White spruce is a long-lived component of many northern forests. It is occasionally damaged during outbreaks of the spruce budworm, though it "handles" defoliation well and most white spruce survive budworm outbreaks. Spruce budworm could become a more serious problem if white spruce and balsam fir increase their presence significantly in the area. Large numbers of these two trees, particularly balsam fir, favor spruce budworm outbreaks. Plantation management may be promoting some insects and pathogens that could lead to future problems for white spruce. At the present time, the health of white spruce trees on the Nicolet is generally good. The following are considered the most important tree health concerns for white spruce:

- Spruce budworm- future outbreaks will occur. Maintaining healthy, vigorous white spruce stands should reduce the levels of tree mortality that occur following outbreaks.

- Monoculture - the idea that plantation monocultures of white spruce can encourage insect and pathogen buildup should be further investigated.

Composition

For this report, we are placing the following tree species into the oak type: northern red oak, northern pin oak, and white oak.

Importance:

On the Nicolet, the oak forest type occupies more than 12,000 acres and makes up approximately 2 percent of the Forest (Figure 30). It is concentrated on the southern end of the Forest.

Forest Type Summary

- Stand age - old age is a significant stress for oak, especially for northern pin oak forests on drier, low nutrient sites.

- Regeneration - young, vigorous oak stands are not well represented at this time.

- Gypsy moth - the establishment of this significant defoliator will create widespread stress on the oak resource.

- Tree vigor - with aging stands and the presence of forest tent caterpillar and gypsy moth, maintaining vigorous stands will be imperative for reducing mortality rates.

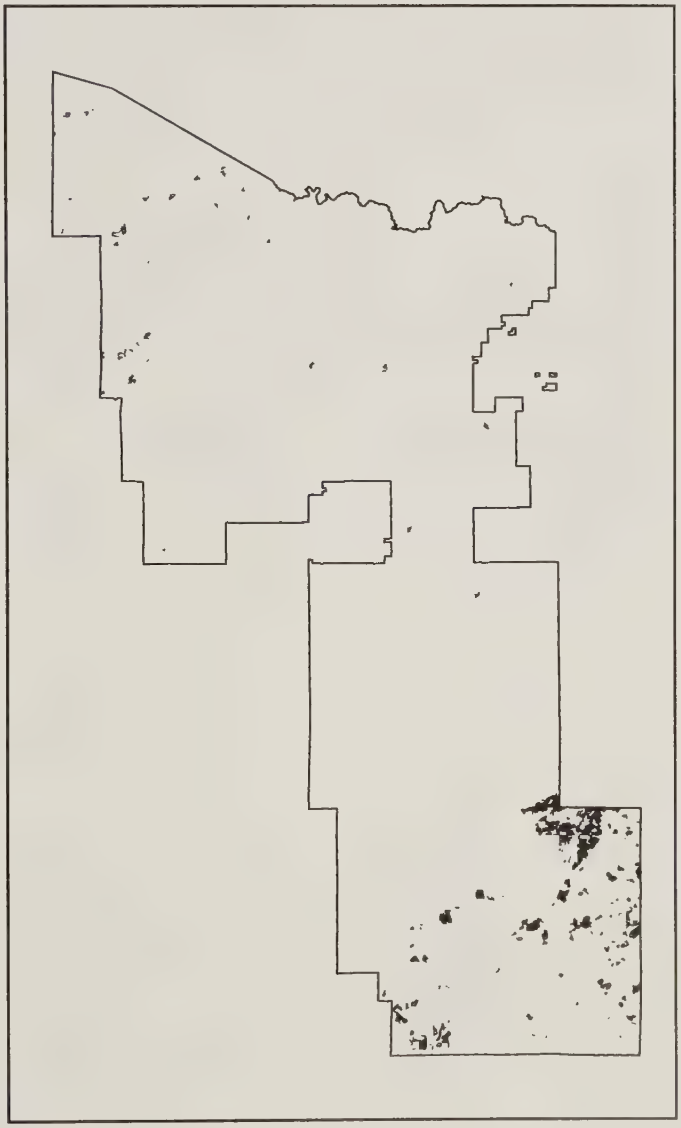

Figure 30. Location of the oak type on the Nicolet.

Oak

The oak forests on the Nicolet are dominated by 65- to 80-year-old stands. This age distribution is a concern for stands dominated by northern pin oak, a relatively short-lived tree, and for red oak stands, which are longer lived but still susceptible to mortality during periods of stress. Between 1987 and 1989, oaks on the Nicolet were severely defoliated by forest tent caterpillar and subjected to a significant drought. Areas of oak mortality were common, especially in older, dense stands on the southern end of the Forest. In the future, maintaining high vigor will be very important in reducing tree mortality, especially once gypsy moth becomes well established in the area.

Oak-dominated forests are not common on the Nicolet, and most are concentrated on the southern end of the Forest. Northern red oak and northern pin oak are the two common oak species on the Nicolet though white oak is also present. On the Nicolet, most of the oak forest is dominated by northern red oak, which becomes the predominant species on slightly more nutrient-rich, mesic sites. On such sites, red oak may grow in relatively pure stands or in mixtures with white oak, red and white pine, aspen, and paper birch. Northern pin oak dominates the oak forest type on dry, nutrient-poor sites.

Northern pin oak is considered intolerant of shade, growing well only in full sunlight. Northern red oak and white oak are both considered intermediate in shade tolerance and can grow under moderate levels of shade when young, but their best growth still occurs in full sunlight. In general, northern red oak and white oak live longer than northern pin oak.

Age Class Distribution

Both the northern pin oak and northern red oak forests (Figure 31) on the Nicolet are dominated by stands that originated between 1915 and 1930, making them 65-80 years old. The few white oak stands on the forest are also within that age class.

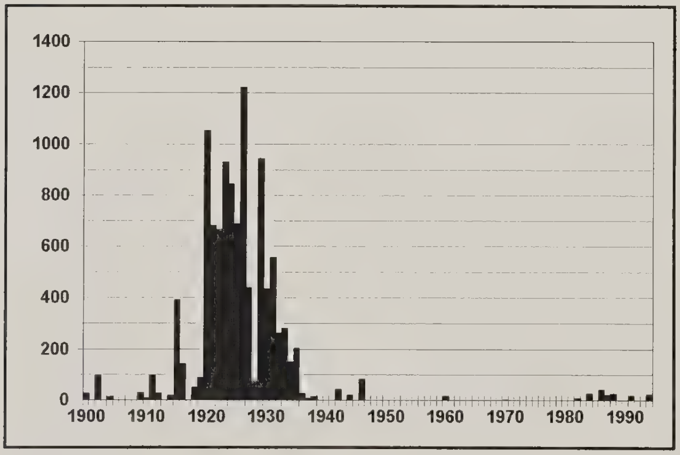

Figure 31. Year of origin of northern red oak stands on the Nicolet.

Historical Disturbance Agents

Historically, oak was apparently not a major species on much of the Nicolet. Those trees present were probably concentrated on the drier sites. Disturbances, such as fires, would have favored oak by setting back succession to an earlier stage. Many of the oak stands currently on the Forest probably originated following fires. Insects and pathogens were likely quite prevalent. Forest tent caterpillar is a native defoliator that would have had regional outbreaks every 7-15 years. Outbreaks lasted about 2-4 years and would have resulted in leaf loss on much of the oak in the area. In the northern pin oak stands, this defoliation would have caused localized spots of tree mortality concentrated in older trees. On the landscape level, this mortality was probably quite minor. In the northern red oak forests, tree mortality would have been concentrated in suppressed and intermediate-size trees and probably acted as a thinning agent. Occasionally, periods of drought may have corresponded with caterpillar feeding, and mortality would have been more severe. Older trees, stressed by defoliation or drought, would have been invaded and killed by Armillaria root disease or

the two-lined chestnut borer. On more nutrient-rich sites, oak was likely replaced by more shade tolerant trees such as sugar maple or by longer lived trees such as white pine. On dry, nutrient-poor sites, the oak forest would have persisted as a sub-climax type.

Recent Disturbance Agents

Recently, drought and insect-caused defoliation have been the two most serious disturbance agents affecting oak stands on the Nicolet. In the early 1990's, oak mortality was common and widespread on the southern end of the Nicolet due to the drought of the late 1980's and an intense outbreak by the forest tent caterpillar. The combination of leaf loss and drought severely stressed trees, making them susceptible to invasion by the two-lined chestnut borer and Armillaria root disease. No formal survey was conducted to estimate the number of oak trees that died, but tree mortality was significant in some stands. Aerial surveys conducted in 1991 found oak mortality on more than 3000 acres in the Lakewood Ranger District.

Future Disturbance Agents

Several significant threats exist for oak-dominated forests on the Nicolet. First, the establishment of gypsy moth will add a major defoliator that will have 1- to 3-year periodic outbreaks in oak stands. In addition, the forest tent caterpillar will continue to have outbreaks every 7-15 years. These two defoliators are capable of creating significant stress in oak stands. Oak trees that are not vigorous will very likely die after outbreaks of these defoliators. In the northern pin oak forests, low vigor trees are generally those older than 60 years. In the northern red oak-dominated forests, low vigor trees are those in the suppressed or intermediate crown classes. These low vigor trees, once defoliated, will be readily infested by the two-lined chestnut borer or Armillaria root disease — either of which can kill them. Current research indicates that healthy, vigorous oak trees can survive periods of defoliation. Therefore, oak can be an important component of future forests in the area, but these forests will need to be kept in vigorous condition.

Oak wilt is another potential threat. This disease is common in central Wisconsin counties and could become more prevalent on the Nicolet. It is favored by springtime injury to oaks and could be introduced into new areas during construction activities or harvesting.

Major Insects and Pathogens

Forest tent caterpillar, *Malacosoma disstria*, is a native caterpillar that reaches outbreak levels every 7-15 years in northeastern Wisconsin (photo - Appendix III). Outbreaks often last for 2-3 years in an area. Aspen and oaks are the two favorite hosts for forest tent caterpillar. In most cases, oaks can be defoliated over a 1- to 2-year period without significant problems. However, if oaks in poor health are defoliated, they can be killed. A simplistic definition of a healthy red oak: a tree with a large crown that is not suppressed by neighboring trees.

Gypsy moth, *Lymantria dispar*, is an exotic caterpillar that has become established in northeastern Wisconsin (photo - Appendix III). Gypsy moth is a well-documented pest of oak. It is difficult to predict when the first significant defoliation by gypsy moths will occur in this area, but defoliation is likely within the next 10 years on the Nicolet. Older stands of northern pin oak and dense, stagnated

stands of northern red oak will be the most likely locations to suffer significant mortality and growth loss. Maintaining vigorous oak stands is the key to reducing mortality levels. This can be accomplished by periodically thinning northern red oak- and white oak-dominated stands and by maintaining younger age classes in northern pin oak stands.

Two-lined chestnut borer, *Agrilus bilineatus*, is a small, native wood-boring beetle that infests and kills oaks weakened by old age, defoliation, drought, or suppression by competing trees. Infested trees can die in a single year, or it may take 3-5 years of successive attacks to kill them. Two-lined chestnut borers were commonly found killing oaks on the southern end of the Forest, especially around Crooked Lake after the drought and forest tent caterpillar outbreak of the late 1980's. Dead and dying oaks were very common at that time.

Figure 32. Range of oak wilt in Wisconsin, 1997.

Oak wilt is a fatal disease caused by the fungus *Ceratocystis fagacearum*. The disease is considered native to Wisconsin and is very common in central Wisconsin counties, but it is not currently common on the Nicolet (Figure 32). It is transmitted by insects that visit fresh wounds in the springtime and, therefore, is often associated with construction and development. It can also be transmitted by root grafts to neighboring oaks, thereby forming pockets of dead and dying trees

Armillaria root disease is caused by several species of fungi in the genus *Armillaria*. These fungi grow as parasites on living tree tissue, most often roots, and on dead woody material in the soil. Armillaria root disease kills trees that are already weakened. In oaks, weakened trees are a result of old age, defoliation, drought, and suppression by competing trees.

Summary

The oak resource on the Nicolet can be divided into two major types: the northern pin oak forests and the northern red oak forests. Both of these are dominated by stands that are 65-80 years old. This is old for northern pin oak, and old-age is a significant stress in that species. Red oak is generally longer lived and, therefore, in better condition. However, both of the major types suffer from a lack of young age classes. A significant threat on the horizon is the gypsy moth, an exotic defoliating insect. Forest tent caterpillar, a native defoliator, will also continue to be active in these oak stands. The two-lined chestnut borer and Armillaria root disease are present and will readily infest any oaks that become stressed.

Composition

For this report, we consider the following species to be the major tree species in the lowland conifer forest: black spruce, tamarack, and northern white-cedar.

Importance

On the Nicolet, the lowland conifer type occupies more than 89,000 acres and makes up approximately 14 percent of the Forest (Figure 33).

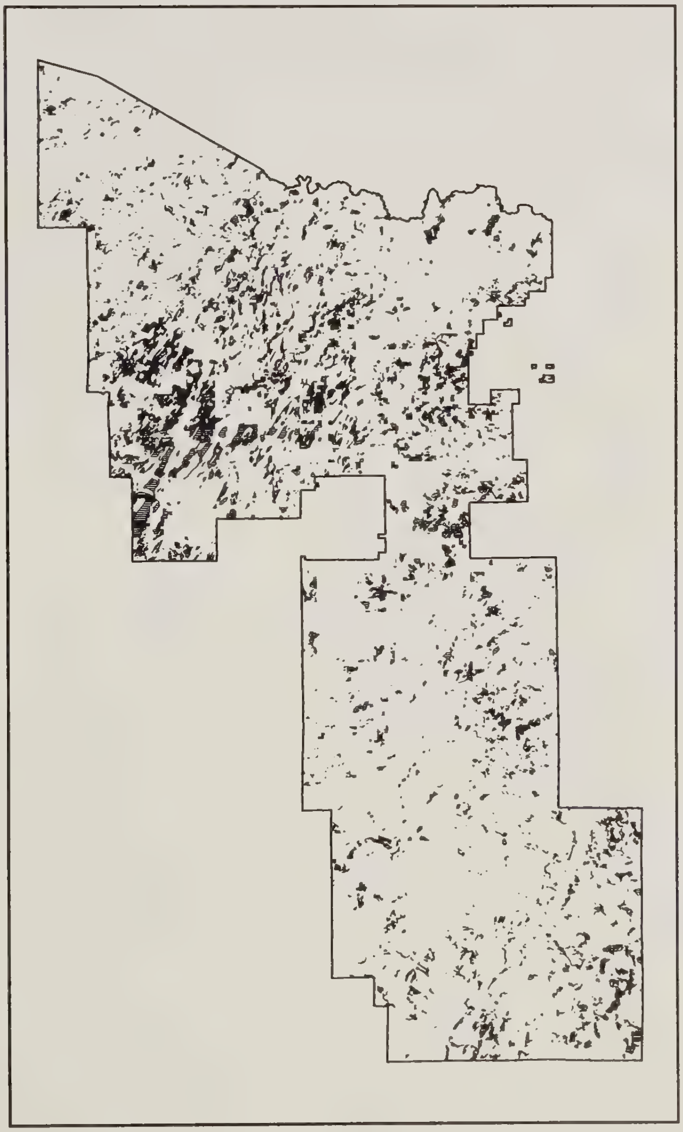

Figure 33. Location of the lowland conifer type on the Nicolet.

Forest Type Summary

- Northern white-cedar continues to experience regeneration problems. Browsing by white-tailed deer and snowshoe hare are contributing factors, but are very likely only part of the problem.

- Tamarack experienced extensive defoliation and mortality in the early part of the century due to two exotic insects, the larch sawfly and the larch casebearer. Since the release of parasitic insects specific to these exotic pests, similar outbreaks have not occurred. Whether these parasites will prevent further serious outbreaks remains to be seen, but to date this appears to be an example of a successful biological control program.

- Black spruce is generally in good health, though some stands are affected by eastern dwarf mistletoe. Past surveys indicated that 25 percent of black spruce stands have dwarf mistletoe present. Five percent of affected stands were experiencing what was considered significant mortality.

- Flooding, generally caused by beaver activity or road construction, is often responsible for killing areas of all the swamp conifers.

Black Spruce

The black spruce resource on the Nicolet is generally in good condition. However, eastern dwarf mistletoe is present on the Forest. The presence of this parasitic plant may make effective black spruce management increasingly difficult in the future.

Black spruce is a small to medium-size member of the lowland conifer forest that is capable of living more than 200 years. It commonly occurs in pure stands or mixed with tamarack on peatlands or mixed with other lowland conifers and hardwoods on mineral soils. A poor competitor, black spruce is usually restricted to wet sites where other tree species are unable to grow. It can be found occasionally on dry, upland sites, often mixed with jack pine. Black spruce is a fire-adapted species with semi-serotinus cones that open fully after fire. Even-aged black spruce stands usually have originated following a fire.

Age Class Distribution

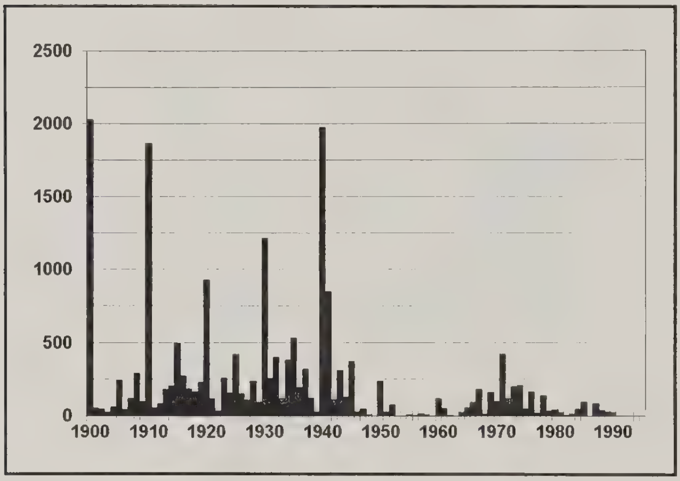

Figure 34. Year of origin of black spruce stands on the Nicolet.

Most black spruce stands on the Forest originated before 1945 (Figure 34). Many of these probably were established after fires.

Historical Disturbance Agents

Fire was the classic disturbance in black spruce stands, though lowlands rarely burned except in extremely dry conditions. Black spruce are particularly susceptible to windthrow because of their shallow roots. Ice storms and heavy snows were a common source of stem breakage and other crown damage. Dwarf mistletoe has long been a component of the black spruce forest and has always caused some tree mortality. Older stands contained numerous trunk rots and root rots including Armillaria root disease. In the past, spruce budworm would occasionally have defoliated black spruce. However, in most cases, black spruce escapes defoliation by budworm caterpillars because it breaks bud and begins growth later in the spring than balsam fir and white spruce.

Recent Disturbance Agents

Dwarf mistletoe is the disturbance agent that causes much of the black spruce mortality on the Nicolet. A 1976 survey reported that of 76 black spruce stands sampled on the Nicolet, 24 percent were found infected by dwarf mistletoe.[40] This tree parasite is more prevalent in noncommercial black spruce stands. Control is often not feasible on these sites, yet these stands serve as a refuge from which dwarf mistletoe is able to colonize adjacent commercial stands.

Although a lowland species, black spruce is vulnerable to changes in the water table and can be easily killed by flooding caused by beaver activity or road construction. Snowshoe hares can severely damage seedling when their numbers are high.

[40] Anderson, R.; Anderson, B.; MacDonald, R. 1976. Dwarf mistletoe of black spruce and broom rust of balsam fir on the Nicolet National Forest. Survey Report S-8-76. Upper Darby, PA: USDA Forest Service, Northeastern Area, State & Private Forestry. 2 p.

Future Disturbance Agents

Dwarf mistletoe will continue to be a problem in black spruce stands. Its presence may increase due to fire suppression and a lack of harvesting activity in black spruce stands. Both fire and some cutting practices could be used to reduce dwarf mistletoe incidence. As stands age, we can expect to see an increase in heart-rots and trunk-rots which will promote windthrow and stem breakage associated with wind, snow and ice storms. This can add to fuel loads that will increase the probability of stand replacing fires. Some minor losses will continue to occur from the spruce budworm during outbreaks as long as balsam fir continues to be a significant component of the forest.

Major Insects and Pathogens

Eastern Dwarf Mistletoe, *Arceuthobium pusillum*, is a parasitic flowering plant that infests black spruce in the Lake States. Infested trees produce large, noticeable overgrowths of branches and twigs called "witches' brooms." These overgrowths function as metabolic sinks, absorbing nutrients and water at the expense of the tree. This nutrient imbalance reduces the vigor of the tree as a whole and eventually kills it. Dwarf mistletoe is capable of infecting healthy trees of all ages, but is most damaging in uneven-aged stands. There the spread of the parasite is much greater as infected overstory trees are able to disperse seeds to susceptible seedlings. Control of dwarf mistletoe can be difficult because of the long rotation ages involved with black spruce management, the difficulties with accessibility into many stands, and the surrounding of much of the "good" spruce stands by unmerchantable severely affected stands. Losses to dwarf mistletoe can be minimized by:

- managing black spruce in even-aged stands
- removing infected trees during harvests
- burning logging slash
- detecting and eradicating infection centers early as they occur.

Summary

Black spruce is an important component of the lowland conifer forest. Overall, no major agent threatens the black spruce resource although many black spruce stands are experiencing damage due to dwarf mistletoe. This parasite causes a loss of growth and premature tree death.

The following is the most important tree health concern for black spruce:

- Dwarf mistletoe continues to threaten black spruce stands. Of particular concern are the many noncommercial stands that serve as a ready inoculum source.

The tamarack resource was decimated in the early 1900's, due to outbreaks of the larch sawfly, an exotic insect. Larch sawfly populations have remained low since the 1950's, apparently due to the establishment of natural enemies of the sawfly from Europe. Tamarack has since recovered, and today has few health problems. However, localized areas of mortality associated with flooding caused by beaver dams or road construction do occur. In the absence of prolonged sawfly outbreaks, the tamarack resource should remain vigorous.

Tamarack, or eastern larch, is a small- to medium-sized tree that is generally restricted to marshes and peat bogs. In northeastern Wisconsin, tamarack is commonly found growing in association with balsam fir, black spruce, northern white-cedar, red maple, and quaking aspen. It can also be found growing in relatively pure stands. Occasionally tamarack grows in upland areas, but it is very intolerant of shade and must become established well in advance of other tree species to survive. Tamarack is considered a moderately long-lived tree with a maximum age of about 150 years.

Age Class Distribution

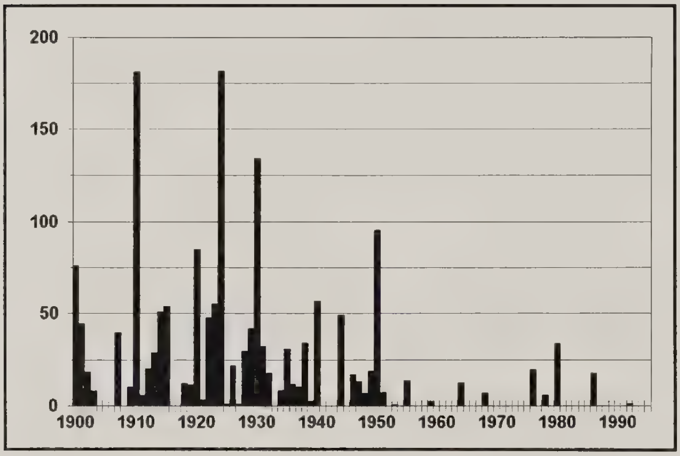

Figure 35. Year of origin of tamarack stands on the Nicolet.

Most of the current tamarack stands on the Nicolet forest became established between 1900 and 1945 (Figure 35). Therefore, most stands are between 50 and 90 years of age.

Historical Disturbance Agents

Tamarack was probably affected a great deal by windthrow in the past because of its shallow root system. Flooding, caused mainly by beaver activity, was an additional localized disturbance. Tamarack can grow on wet soils but a small fluctuation in water levels can kill it. Fires, though they rarely occur in wetlands, were probably a significant disturbance. Fire easily kills tamarack because of its thin bark and creates very favorable site conditions for establishment of new tamarack stands.

Insect defoliators apparently were not a major disturbance agent historically. However, this changed around 1900 with the introduction of larch sawfly into the Great Lakes Region. An outbreak of larch sawfly between 1906 and 1912 in Michigan's Upper Peninsula resulted in mortality levels that approached 40-100 percent in many stands.[41] The same outbreak also affected northeastern Wisconsin.[42] Another intense outbreak was recorded in the region between 1925 and 1930, which resulted in further mortality.

Larch casebearer is another exotic defoliator that was introduced into North America in 1886. It moved into the Great Lakes Region in the 1920's and 1930's, initially causing widespread defoliation. However, the release of several parasites from Europe against this insect has significantly reduced its incidence since the 1940's.

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[41] Graham, S. 1956. The larch sawfly in the Lake States. Journal of Forestry. 2: 132-160.

[42] Curtis, J.T. 1959. The vegetation of Wisconsin. Madison, WI: University of Wisconsin Press. 657 p.

Recent Disturbance Agents

Larch sawfly has had localized outbreaks in Wisconsin in recent years. However, widespread intense outbreaks have not been reported in the Lake States Region since the late 1950's. Introduction and establishment of two European parasites of larch sawfly may be playing an important role in maintaining larch sawfly populations at lower levels than during the first half of the 20th century. However, it may be that larch sawfly populations will again rise to outbreak levels and create problems in tamarack stands. No severe outbreaks of larch casebearer have been reported on the Forest in the past 30 years.

Flooding continues to be a common cause of mortality in localized areas. A general increase in beaver populations during the past 10-20 years has increased the number of beaver dams in many areas. Also, road building and poor maintenance of culverts can affect water levels and water movement, resulting in groups of dead tamarack along roads.

Future Disturbance Agents

The tamarack resource in northeastern Wisconsin is getting older and larger. Therefore, damaging agents associated with older stands will increase in prevalence, specifically windthrow related to root and stem decay. Older trees may also increase the incidence of the larch bark beetle, *Dendroctonus simplex*, which is associated with windthrow and older, decadent trees.

The role that larch sawfly or larch casebearer will play in the future is still unknown. It is feasible that the biological control programs targeted at these two exotic insects have been successful and will result in fewer and less intense outbreaks in the future.

A new exotic threat may be gypsy moth, which feeds readily on tamarack. However, gypsy moth outbreaks often last only 1-2 years in any given stand. Past observations of larch sawfly indicate that it can take 5-7 consecutive years of defoliation to kill mature tamarack trees. Therefore, defoliation by gypsy moth may occur, but tree mortality seems unlikely.

Major Insects and Pathogens

Larch sawfly, *Pristophora erichsonii*, was first recorded in North America in 1880, and the first outbreaks in the Lake States were reported between 1900 and 1910. Larval feeding occurs in early summer and can result in complete needle loss (photo - Appendix III). However, tamarack trees are capable of refoliating and are very tolerant of defoliation. Thus, it can take 5-7 years of heavy defoliation before tree mortality begins. Two parasitic wasps, introduced from Europe, play a significant role in maintaining larch sawfly populations at reasonable levels. The presence of these two parasites may be the reason that widespread, prolonged larch sawfly outbreaks have not occurred in the region since the 1950's.

Larch casebearer, *Coleophora laricella*, a native of Europe, was introduced into North America in 1886. It reached the Lake States in the 1920's, resulting in several years of intense outbreaks. These outbreaks prompted both the U.S. and Canada to initiate biological control programs in the 1930's and 1940's aimed at finding natural enemies of the larch casebearer in its native Europe. The eventual introduction and establishment of two parasitic wasps has apparently eliminated larch casebearer as a significant defoliator of tamarack.

Summary

The tamarack resource is increasing in age and size, and it appears to be relatively healthy. Localized areas of mortality are generally associated with flooding caused by beaver or road building activity. Larch sawfly and larch casebearer are two exotic defoliators that in the past (1900-1960) have caused significant mortality in tamarack stands. However, outbreaks since 1960 have been rare and very short in duration. The reason for the reduction in outbreak intensity is still not clear, and the future likelihood of widespread outbreaks by these insects is difficult to predict at this time. Gypsy moth may cause short-term periods of tamarack defoliation in the future, but this should not cause any significant impacts. The major tree health concerns in tamarack are:

- Exotic defoliators - the future prevalence of larch sawfly, larch casebearer, and gypsy moth will be important in determining the health of tamarack stands.

- Incidence of flooding - tamarack dies readily if water levels rise.

Northern White-cedar

Northern white-cedar is a common tree of wetlands on the Nicolet. No major insect or disease problems exist. However, there are concerns over the species ability to regenerate. Deer have been blamed for much of the lack of regeneration.

White-cedar is one of the dominant conifer species of the lowland forest and can be found in pure and mixed stands. A long-lived mid-successional tree, white-cedar can reach ages of 400 years on lowland mesic forests. White-cedar was formerly more widespread across the Forest than it is currently. Today white-cedar is largely restricted to dense swamp stands, or other wet sites mixed with balsam fir, black spruce, and tamarack. Currently, there are concerns related to regenerating white-cedar. High deer populations have been blamed for much of this because white-cedar is a highly favored deer browse. It is common to see white-cedar "pruned" up as high as the deer are able to reach. Additionally, white-cedar swamps are favorite winter deeryards, and any regeneration in those areas is quickly consumed. However, besides deer, other regeneration difficulties may also be occurrring.

Age Class Distribution

The vast majority of white-cedar stands on the Forest originated before 1900 (Figure 36). Since then, very few new stands have been established. Because of the longevity of white-cedar, this imbalance is not as critical as with some other species, but it does indicate a potential problem with the white-cedar resource. Diameter distribution data for the Forest indicate a possible shortage of trees in the smallest diameter classes,[43] which may indicate a regeneration problem in northern white-cedar (Figure 37).

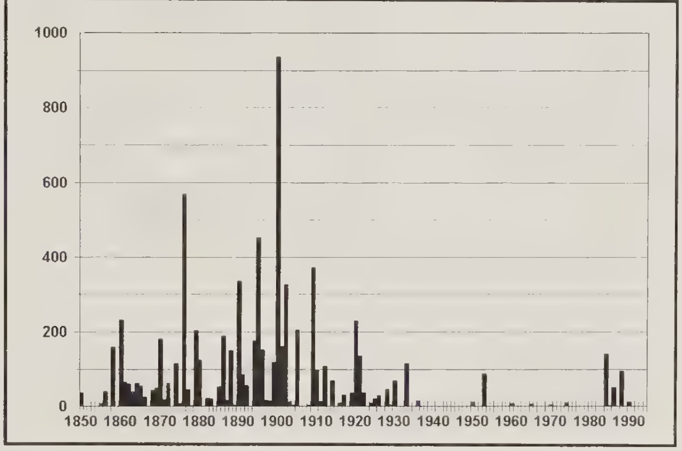

Figure 36. Year of origin of white-cedar stands on the Nicolet.

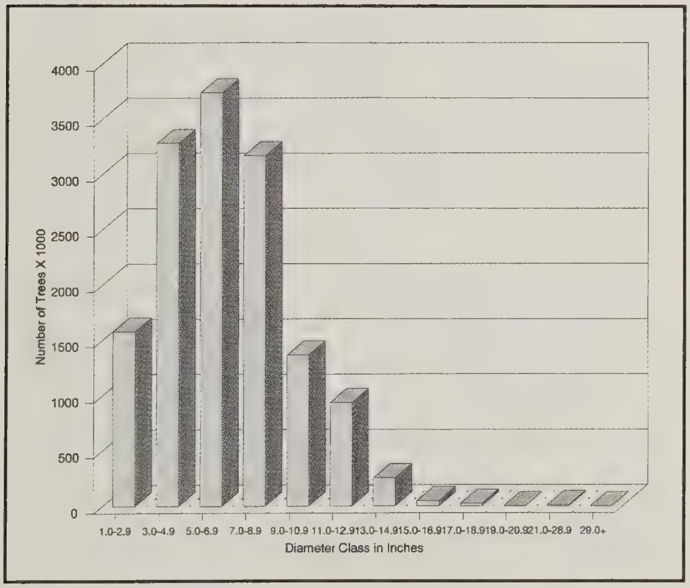

Figure 37. Number of white-cedar trees by diameter class, Nicolet National Forest, 1996, FIA inventory.

Historical Disturbance Agents

Historically, northern white-cedar had no major insect or pathogen pests. It does, however, have a thin, highly flammable bark and a shallow root system, so fire was probably an important, though relatively rare, disturbance. White-cedar is also very sensitive to changes in water level and water movement. Therefore, flooding due to beaver activity would have killed white-cedar in localized areas. Snowshoe hares and deer also browsed white-cedar. Drought was also important, especially for seedlings that became established on moss or hummocks prone to quickly dry out. Windthrow was probably common since white-cedar has a shallow root

[43] Forest Inventory and Analysis, USDA Forest Service, Nicolet 1996 data.

system. Overall, based on the tree's ability to live a long life, its lack of insect or disease problems, and its growth in areas not prone to fire, white-cedar dominated forests were probably very stable.

Recent Disturbance Agents

White-cedar has been declining on the Nicolet. The 1997 Forest-wide inventory shows a decrease in the number of white-cedar trees on the Forest between 1983 and 1996.[44] The reasons for that decrease are not well understood. No exotic insects or pathogens threaten white-cedar. In the Lake States, poorly constructed roads that can alter water movement have killed areas of white-cedar as well as other swamp conifers.[45] Beaver activity can also kill areas of white-cedar. However, no large areas of white-cedar mortality associated with flooding or road building have been reported on the Nicolet. White-cedar along major roads is susceptible to injury from deicing salt. This injury can be seen across northern Wisconsin, but it is not responsible for dieback except in a few localized areas along highways. Regenerating white-cedar has been identified as an important concern in recent years. Deer are considered by many to be one of the major factors limiting white-cedar regeneration, especially in deeryards. However, the importance of deer browse on the Forest has not been documented. Snowshoe hares, whose populations fluctuate widely, also browse young white-cedar and also could play an important role in reducing the numbers of young white-cedar trees.

Future Disturbance Agents

High deer populations, as well as other issues related to regenerating white-cedar, will continue to cause concern in establishing white-cedar.

Major Insects and Pathogens

Northern white-cedar has few major native insects or pathogens that pose a serious threat to the resource. As in all species, a small amount of tree mortality occurs annually in white-cedar due to various insects and diseases, but the overall impact to the long-term health of the species is minimal.

Arborvitae Leafminer, *Argyresthia thuiella*, is a tiny leafmining insect that occasionally attacks natural and ornamental northern white-cedar in the Eastern United States and Canada. Leafmining by this insect causes needles to turn yellow or brown, giving the tree a "scorched" appearance. Light infestations are relatively insignificant, but heavy infestations can result in branch loss or tree death. Although *A. thuiella* is the most common, three other *Argyresthia* species can be found during outbreaks. These insects feed only in the spring, and damage usually appears by early summer. Trees are normally able to replace the damaged foliage, although refoliation does stress the trees.

Summary

Northern white-cedar is a long-lived, mid-successional species that is largely free of major disease or insect problems. However, concern does exist for white-cedar because of its preponderance of older stands and few young stands. Seedling mortality due to browsing by white-tailed deer and snowshoe hare is contributing to this problem, though it is likely that other regeneration problems also exist. The following is the most important tree health concern for northern white-cedar:

- Regeneration - the issue of regenerating white-cedar should be addressed and the role that deer and snowshoe hare play should be clarified.

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[44] Forest Inventory and Analysis, USDA Forest Service, Nicolet 1996 data.

[45] Stoeckeler, J. 1967. Wetland road crossings: drainage problems and timber damage. Research Note NC-27. St. Paul, MN: USDA Forest Service, North Central Experiment Station. 4 p.

Composition

For this report, we are considering black ash, red maple, and American elm to be the principal members of the lowland hardwood forest.

Importance

On the Nicolet, the lowland hardwood forest occupies more than 11,000 acres and makes up approximately 2 percent of the Forest (Figure 38).

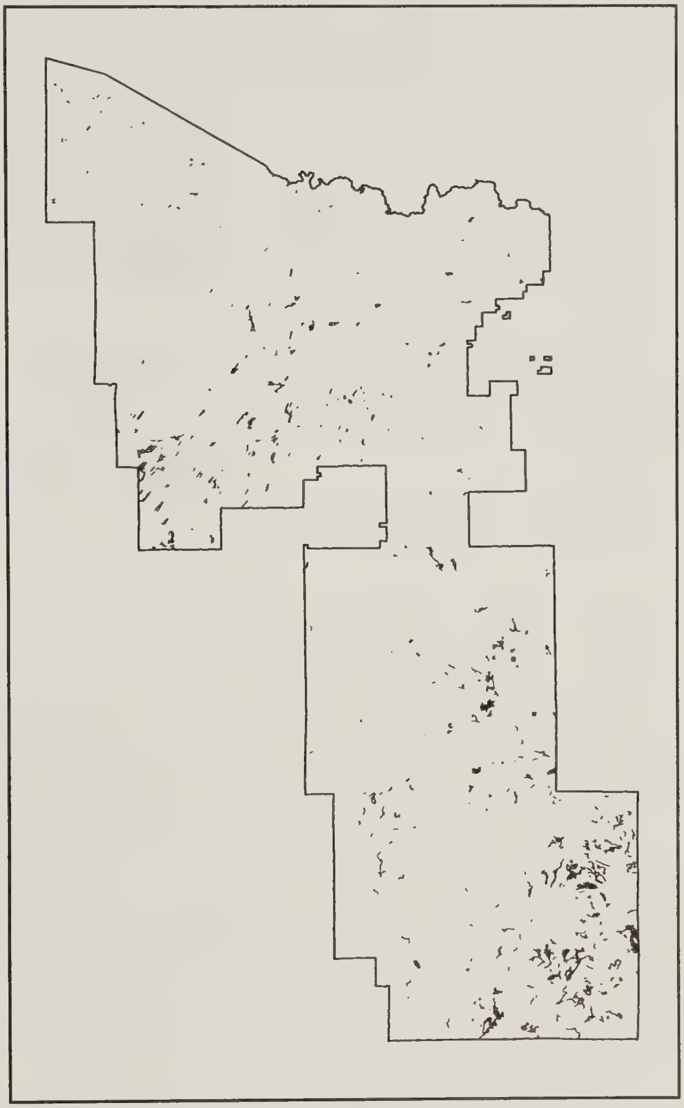

Figure 38. Location of the lowland hardwood type on the Nicolet.

Forest Type Summary

- American elm was formerly an important component of this forest type, but Dutch elm disease introduced to the Forest in the 1960's has eliminated virtually all large elm trees. Because smaller elm trees are less likely to die, the species still exists on the Forest, but it has been reduced to a minor understory tree.

- With the loss of American elm, black ash and red maple have become the two dominant lowland hardwood trees. This has resulted in larger areas of either pure black ash or pure red maple. These areas of monoculture may tend to promote insect and disease activity within these types.

- Black ash is currently recovering from a serious episode of ash dieback that resulted in extensive branch dieback and mortality in black ash stands all across the Lake States. The dieback and mortality probably began with the drought of the late 1980's, which seriously stressed the lowland forest, although excessive mortality of black ash did not occur at the time. Then, in the summer of 1991, an outbreak of ash anthracnose defoliated ash trees. The following spring and summer, northern Wisconsin had two late frosts, which killed the newly developing leaves of black ash. After this series of events, extensive dieback and mortality of black ash occurred.

Black Ash

The black ash resource is currently recovering from a recent episode of ash dieback, a phenomenon that resulted in widespread dieback and mortality of black ash trees all across the Lake States.

Black ash is a medium-size, slow-growing, moderately long-lived tree. It occurs primarily in low-lying areas along streams and in swamps and is able to tolerate inundation for short periods of time. Black ash occasionally occurs on uplands, where it grows quite well, but is rarely able to become established due to competition. With the elimination of American elm, it has been expanding its presence within the lowland forest type, resulting in large areas of nearly pure black ash. The vulnerability of a black ash monoculture was clearly demonstrated by a recent episode of ash decline and mortality that occurred across the Lakes States in the early 1990's. Today, most black ash stands are still in the process of recovering from this episode.

Age Class Distribution

Most of the black ash stands on the Nicolet were established between 1920 and 1940 (Figure 39). Since 1950, very few new stands have been established. Despite this, the number of black ash trees have probably increased because they have replaced American elm in the lowland hardwood forest.

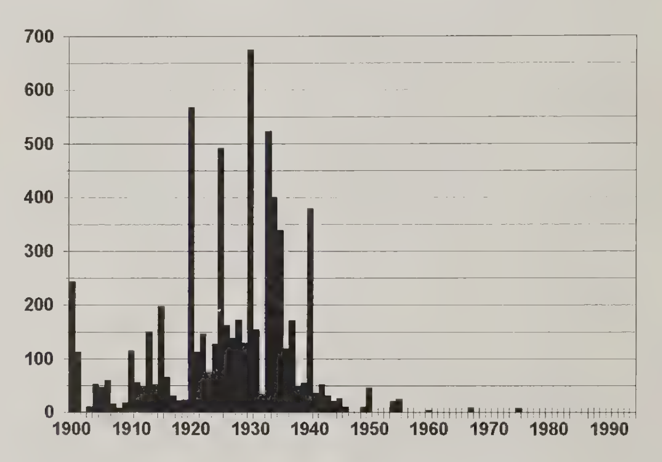

Figure 39. Year of origin of black ash stands on the Nicolet.

Historical Disturbance Agents

Very little documentation of disturbance specific to black ash exists. Most losses were probably due to the many root, trunk, and butt rots to which black ash is especially susceptible. Black ash is also susceptible to many of the general hardwood defoliators and pathogens that inhabit the northern hardwood forest, although none have been particularly damaging in the recent past. Fire was probably insignificant except after prolonged drought. Because of the shallow-rooted nature of ash, windthrow was responsible for periodic damage. Furthermore, root rots such as Armillaria root disease probably contributed to additional windthrow. Black ash would also have been vulnerable to water table fluctuations caused by flooding or long-term drought.

Recent Disturbance Agents

Reduced diversity in the lowland forest may be exacerbating the impact of some native disturbance agents. For instance, a leaf disease called ash anthracnose has caused significant problems in recent years. Anthracnose was a contributing factor in the recent episode of ash decline that occurred across the Lake States. The decline was the result of an outbreak of ash anthracnose in the summer of 1991, followed by a series of late spring frosts in 1992, including an unusual frost on June 20. Residual effects from the 1987-89 drought also played a role in the widespread dieback and mortality that occurred. Today, most black ash stands are still in the process of recovering from this series of events. Black ash usually avoids frost damage by leafing out very late in the spring. Nonetheless, frost can be a problem, especially for regeneration, because cold air settles in lowland sites. Flooding, caused by beaver activity, has become a common occurrence due to recent increases in the beaver population. This has resulted in pockets of black ash mortality across the Forest. Road building can also alter drainage, which has occasionally flooded lowland areas and killed trees.

Future Disturbance Agents

The continued lack of diversity within black ash-dominated forests will continue to make the resource more susceptible to insect and disease damage. Relatively pure ash forests will be very susceptible to frost injury and diseases such as ash anthracnose. In addition, as the resource continues to age, heart and root rots will become more prevalent and contribute to increased windthrow, which will promote gap formation within black ash stands. If the current upward trend in beaver populations continues, additional tree mortality will occur as a result of flooding. In addition, high deer and hare populations may be detrimental to regeneration of black ash, which is a favored browse species.

Major Insects and Diseases

Ash anthracnose is a leaf disease caused by the fungus *Gnomoniella fraxini*. This disease develops during wet weather, usually in the spring, and causes leaf deformation and defoliation. The disease is not normally a serious threat because the trees are able to refoliate, though refoliation does cause some tree stress. If an anthracnose outbreak occurs with other stresses acting on the tree, the results can be much more serious. This was the case in the early 1990's when a series of severe frosts and an anthracnose outbreak occurred shortly after a prolonged drought and caused widespread dieback and mortality.

Armillaria root disease, caused by *Armillaria* spp., is a very common root-rot fungal disease. The fungi sustain themselves on both living and dead plant material, though they usually only attack live trees that are under stress. This tendency makes this disease especially important in old stands. The abundant substrate from dead and dying trees favors the growth of the fungus and allows it to more easily colonize other stressed or older trees. Armillaria root disease contributes to increased windthrow in older stands and promotes age-class and species diversity by creating canopy gaps.

Summary

Black ash is currently increasing its presence on the Forest, which is creating a black ash monoculture on some wet sites. This reduced diversity may be contributing to tree health problems. Evidence for this is the recent widespread episode of ash decline that occurred across the Lake States in the early 1990's. The ash resource is still recovering from this event. The following are the most important health concerns in the black ash-dominated forests:

- Age-class and species diversity is limited. This has created monoculture stands that may be more prone to health problems than more diversified stands are.
- Flooding or drought can alter water tables, causing decline or outright tree mortality. Beaver activity, road construction, or other practices that alter water levels can affect the health of black ash trees.

Red Maple

Red maple is currently expanding its presence on the Forest. At this time, there are no major threats to the health of the red maple resource.

Red maple is one of the most versatile trees on the Nicolet. Often referred to as soft maple, this tree can survive under a wide variety of moisture and nutrient conditions. It is most common in the lowland hardwood forest, but a significant volume also occurs in the northern hardwood, aspen-birch, and lowland conifer forests. Red maple matures at around 70 to 80 years and seldom exceeds 150 years. This species tolerates shade and frequently exists as part of the understory, although it is less tolerant than sugar maple, which often succeeds red maple on better sites. Red maple acts as a pioneer species on mesic upland sites, but forms an edaphic climax on wetter sites. It thrives on disturbance and quickly takes advantage of openings in the forest. In recent years, red maple has expanded its presence within the lowland forest. This is partially due to the loss of American elm and to fire suppression, because fires easily kill red maple trees.

Age Class Distribution

Few stands on the Nicolet are dominated by red maple. Most of those that do exist originated between 1920 and 1940 (Figure 40). The vast majority of red maple trees are found in other forest types, and many young red maples are present on the Forest.

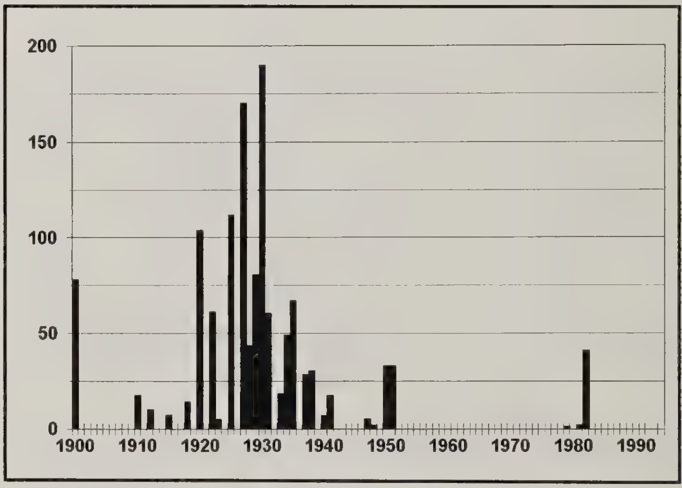

Figure 40. Year of origin of red maple stands on the Nicolet.

Historical Disturbance Agents

Little information exists about disturbance agents that affected red maple in the past. Most abiotic disturbances actually benefitted red maple as they gave this tree an opportunity to become established within stands dominated by other species. Fire was one exception to this because red maple is very sensitive to fire injury; ground fires were capable of killing even mature trees. Although a single fire often promoted vigorous sprouting, repeated fires will eliminate the species. Red maple was host to a large number of insects and pathogens, which individually were not significant, but which collectively caused considerable injury. The most damaging agents to red maple were the heart rots, canker rots and canker diseases, which resulted in most red maple mortality.

Recent Disturbance Agents

Few disturbance agents have adversely affected red maple in the recent past. Red maple injures easily during harvesting or thinning activities, which gives various stain and decay fungi a chance to invade. However, in many cases, harvesting activities create conditions favorable to increased regeneration of red maple trees. Although red maple is quite tolerant of temporary inundation, occasional mortality in low lying areas can occur because of flooding caused by beaver activity. White-tailed deer favor red maple as a browse species and can cause considerable browse damage.

Future Disturbance Agents

As the current population of trees ages, heart and trunk rots will become more prevalent. Stems weakened by decay will contribute to increased windthrow and gap formation. If the current upward trend in the beaver population continues, additional tree mortality will occur as a result of flooding. High deer populations may inhibit regeneration of red maple in some localized areas.

Major Insects and Pathogens

Canker rot, caused by the fungus *Inonotus glomeratus*, is probably the most important decay-causing organism affecting red maple. This pathogen infects the main bole of the tree through wounds or more commonly through dead branch stubs. From this point of entry, the fungus invades the heartwood of the tree where it causes a white rot. The fungus usually forms a black crusty conk on trees after extensive decay occurs, but this feature is often inconspicuous on red maple. There is no available treatment for this disease. To minimize losses, avoid practices that cause injury to trees.

Mossy top fungus - This decay-causing fungus gets its name because moss often grows on the upper surface of the otherwise white conks it produces. The causal agent, *Oxyporus populinus*, often invades wounds, branch stubs, or cankers found on the lower bole of the tree. The fungus produces a localized column of white rot in both the heartwood and sapwood of the tree. There is no treatment available for this disease. Avoiding injury to trees and removing infected stems to reduce inoculum sources should minimize losses to this fungus.

Summary

The current health of red maple on the Nicolet is good, and the presence of this tree appears to be expanding on the Forest. There are no major impediments to the health of red maple. The most important point in maintaining the health and vigor of red maple may be to avoid mechanical injury to the tree.

American Elm

American elm has been eliminated as a dominant tree species on the Nicolet due to Dutch elm disease. This disease — clearly demonstrates — the serious threat that exotic organisms pose to the Forest.

American elm was formerly a dominant overstory species on the Nicolet, particularly in lowland hardwood stands. This versatile tree also grew in uplands and even thrived on some fairly dry sandy and rocky sites. On the Nicolet, the greatest concentrations of American elm occurred on lowlands, although the greatest volume grew in the northern hardwood type. Elm was a long-lived species and often achieved ages of 200-300 years, with diameters of up to 60 inches. While American elm is still found on the Forest, Dutch elm disease has reduced it to a relatively minor understory species. The elimination of elm as a dominant species of the lowland forest has changed the dynamics of the lowland type.

Age Class Distribution

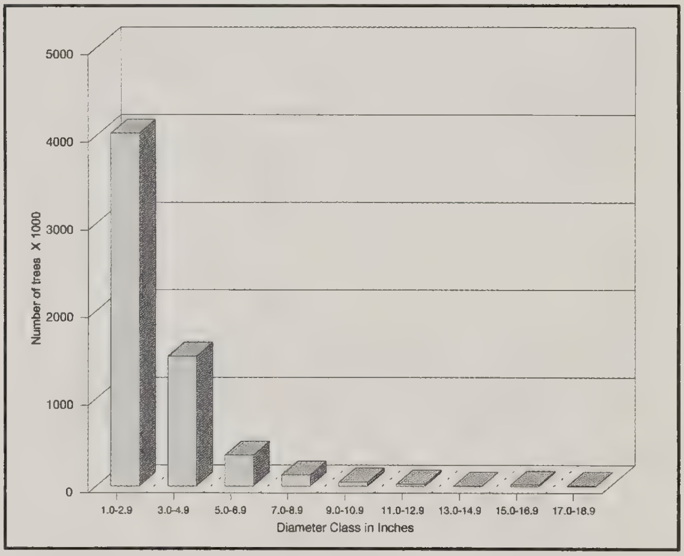

Figure 41. Number of American elm trees by diameter class, Nicolet National Forest, 1996, FIA inventory.

Few older American elms are left on the Forest. Most large trees have died leaving most of the remaining population in the younger age classes. More than 90 percent of the elms on the Forest today are less than 5 inches in diameter (Figure 41). These trees will become susceptible to Dutch elm disease as they get larger and most will die from the disease.

Historical Disturbance Agents

Historically, American elm had no major disturbance agents that caused widespread mortality. Nearly all of the general hardwood-defoliating insects also fed on elm and would have caused growth loss or mortality during outbreaks, but they were generally unimportant. Elm was also host to a number of foliar pathogens, but like the insect defoliators, they did not cause major disturbance. Additionally, elm hosted a number of bark beetles and wood-boring insects, as well as many root and trunk decays and vascular pathogens. Probably the most import disturbances were wind, along with ice and snow damage, that occasionally caused extensive branch breakage because of the species very large crowns and extremely fine branches.

Recent Disturbance Agents

Dutch elm disease was first reported in Wisconsin in 1956, and was found statewide in less than 20 years (Figure 42). By 1978, 50 percent of all elm trees in Wisconsin's forests had died. In a 10-year period from 1968 to 1978, roughly 500 million board feet of elm died across the state.[46]

In the mid-1960's, Dutch elm disease was first reported on the Forest. Over the next several years, this disease quickly spread throughout the Nicolet, leaving thousands of dead elm trees in its wake. No effective control for this disease in a forest situation was available. Most large elms were harvested either as salvage or in anticipation of mortality. Today, few large mature American elm trees exist on the Forest.

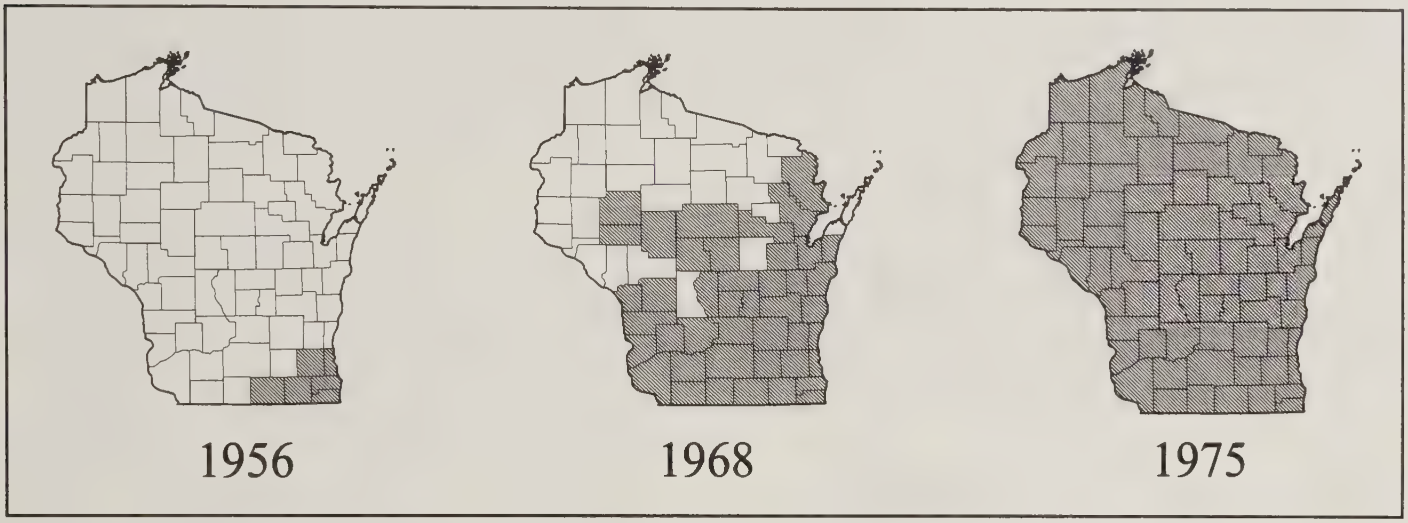

Figure 42. Dutch elm disease quickly spread throughout Wisconsin, 1956-1975

Future Disturbance Agents

Dutch elm disease will continue to kill elm trees. Fortunately, seedling and sapling elms are rarely infected. Elm trees as young as 15 years are sexually mature, so most trees are able to reproduce before eventually succumbing to the disease. Therefore, elm will remain a component of many stands, but it will be limited to small trees.

Major Insects and Pathogens

Dutch elm disease, is a vascular wilt disease caused by the fungus *Ophiostoma ulmi*. This exotic disease is responsible for killing hundreds of thousands of elm trees all across the Eastern United States. The disease is transmitted by the native elm bark beetle, by the smaller European elm bark beetle, or by root grafts. Elm trees often escape Dutch elm disease as seedlings or saplings, but become increasingly likely to become infected as they grow larger. Trees usually reach reproductive age before they contract the disease. Therefore, plenty of seedling and juvenile elms are still around and we are not in danger of losing the species entirely. However, it appears unlikely that elm will ever regain the position in the forest that it once held.

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[46] Department of Natural Resources. 1978. Forest Pest Conditions in Wisconsin. Annual Report 1978. Madison, WI: Department of Natural Resources, Division of Resource Management, Bureau of Forestry. 16 p.

Summary

The introduction of Dutch elm disease has nearly eliminated large American elms on the Forest. However, because small elm trees are rarely infected, there is still a reproducing population of American elm.

Composition

For this report, we are placing the following tree species into the aspen-birch type: quaking aspen, bigtooth aspen, balsam poplar, and paper birch.

Importance

On the Nicolet, the aspen-birch forest type occupies more than 136,000 acres and makes up approximately 22 percent of the Forest (Figure 43).

Figure 43. Location of the aspen-birch type on the Nicolet.

Forest Health Summary

- Aspen stands rapidly deteriorate after age 50-60. At this time, the age distribution for aspen stands on the Forest indicates that most stands are relatively young, less than 40 years old, and from an age standpoint, in relatively good vigor. However, older stands do occur and increased mortality should be expected as the resource ages.

- The age distribution of paper birch stands on the Forest is skewed heavily to older stands, which are susceptible to periods of increased mortality after droughts and insect outbreaks. Very high levels of paper birch mortality were reported in the early 1990's. Few young stands are being established to replace the older, deteriorating stands.

- Significant site disturbance is essential when regenerating this forest type. All of the species are considered intolerant of shade and require full sunlight for survival and growth.

- Several exotic insects that feed on the leaves of both aspen and paper birch have become established on the Nicolet and will result in more frequent defoliation events in future years. Specifically, gypsy moth and birch leafminers may impact the overall health and vigor of aspen and birch stands. Native defoliators, such as forest tent caterpillar, will also remain active and further compound the effects of the exotic leaf feeders.

The current age distribution of aspen stands on the Nicolet indicates that most have originated since 1960. Aspen trees younger than 40 years of age are generally vigorous and healthy, but aspen stands rapidly deteriorate past the age of 50 years. This deterioration is generally associated with an increase in the amount of stem decay as aspen ages.

Quaking aspen is a short-lived, fast-growing pioneer species that typically occurs on sites that range from dry, nutrient-poor to mesic, nutrient-rich. Occasionally it can also be found on very wet sites. Quaking aspen reproduces primarily vegetatively by forming suckers from its root system. However, as a pioneer species, its seeds are dispersed by wind over long distances and can become established wherever mineral soil has been exposed. Quaking aspen is very intolerant of shade and will only develop in full sunlight. Stands generally deteriorate sometime between the ages of 50-70. Historically, quaking aspen was much less abundant than it is today on the Nicolet. Site disturbances such as clearcutting produce site conditions very favorable to aspen.

Age Class Distribution

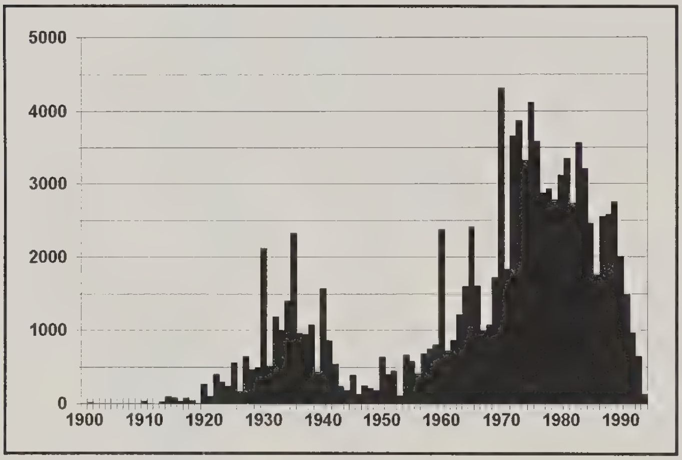

Figure 44. Year of origin of aspen dominated stands on the Nicolet.

On the Nicolet most quaking aspen stands have originated since 1960 (Figure 44). Therefore, the aspen resource on the Forest is relatively young, though older stands, between 50 and 70 years of age, do exist.

Historical Disturbance Agents

Historically, aspen stands developed after large-scale disturbances, typically wildfires or large windstorms. After 50-70 years, these stands would begin to deteriorate. The deterioration of an aspen stand begins when the crowns of older trees can no longer grow fast enough to fill the voids in the canopy left by dying trees. Increased breakage from wind, ice, and snow speeds the process, which can take from 5 to 20 years to complete. By the age of 60-80 years, many aspen trees would have died and succession to more shade-tolerant tree species would have begun. White trunk rot and Armillaria root disease were probably very prevalent in older trees, eventually causing them to break in wind storms or to die outright. Native forest insects often reached outbreak status in quaking aspen stands. Forest tent caterpillar and the large aspen tortrix are two native leaf feeding caterpillars that have a history of outbreaks in the Lake States. Several other native caterpillars have had infrequent, yet widespread outbreaks in aspen stands. These outbreaks stress older aspen and can increase tree mortality.

Most aspen stands on the Nicolet are younger than 40 years of age. Based on age, the resource should be relatively healthy. However, some of these young stands, along with many older stands, were severely affected by an intense forest tent caterpillar outbreak that overlapped with the drought of the late 1980's (Figure 45). Defoliation and drought combined to cause widespread decline in aspen stands, especially on the southern end of the Forest. This decline in growth and overall vigor could still be seen as late as 1994 on parts of the Forest.

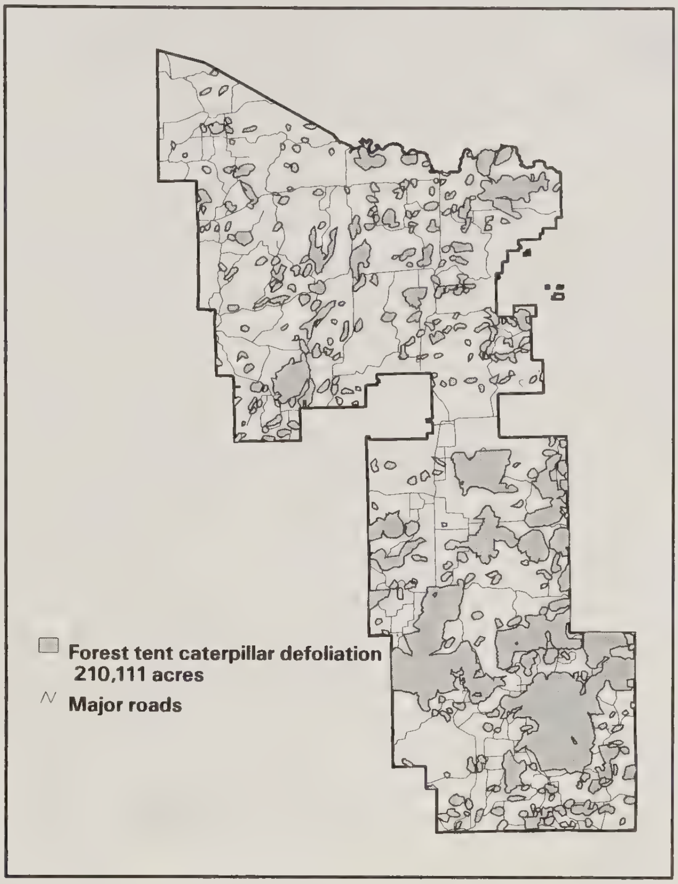

Figure 45. Stands defoliated by forest tent caterpillar in 1990, Nicolet National Forest. Most of the defoliated stands were aspen dominated.

Occasional periods of widespread defoliation of aspen have been common across northeastern Wisconsin, generally from forest tent caterpillar or the large aspen tortrix (Table 1).

Table 1. Major outbreaks of important aspen defoliators in northeast Wisconsin since 1953. Information obtained from Wisconsin DNR, annual reports of forest pest conditions.

Forest tent caterpillar	Large aspen tortrix
1953-1955	1957
1957-1959	1964-1965
1987-1993	1970
	1972-1975

Aspen stands older than 50-70 years are often in an advanced stage of stand deterioration. White trunk rot, a common wood decay of aspen, is very prevalent in these older trees. In the absence of any major stand disturbance, many of these older aspen stands will begin to break up and eventually succeed to more shade tolerant species.

In most young aspen stands that develop after clearcutting, stem density is very high. These young stands begin a process of self-thinning, and mortality of young stems is frequent and not an indication of a health problem. Venturia shoot blight is a commonly encountered disease in young regenerating stands. This fungus kills the growing shoot, which turns black and curls over forming a "sheperds crook." On rare occasions this disease can seriously impact regeneration, but usually is of little

consequence to the rapidly growing sprouts. As long as the initial stand density is high, a well-stocked, vigorous stand generally develops. Low density in juvenile stands is a concern because young stands that develop at low densities are often severely affected by several insects or diseases, such as Hypoxylon canker, and the result can be very poorly stocked stands with excessive amounts of stem breakage and tree mortality.

In 1984 a survey of aspen diseases on the Nicolet revealed that for aspen aged 20-39 years the most common diseases were Hypoxylon canker and white trunk rot. In aspen aged 40-59 years the most common diseases encountered were Nectria canker (*Nectria galligena*) and white trunk rot. The report noted that the overall incidence of disease was low for all stands surveyed.[47]

Future Disturbance Agents

White trunk rot and other decay organisms will continue to be prevalent in older aspen stands, especially stands more than 50-70 years of age. In older stands, stand deterioration will occur quickly as it has in the past. Without active management, aspen stands will succeed to another type. During the lifetime of a stand, episodes of intense defoliation by native caterpillars (i.e., forest tent caterpillar and aspen tortrix) should be expected every 7-15 years. In addition, gypsy moth outbreaks will begin to occur in aspen stands on the Nicolet, probably within the next 5-15 years. Gypsy moth outbreaks should not cause widespread mortality in aspen, but they will be an additional stress factor that can reduce growth rates and increase the speed at which older stands deteriorate.

Maintaining a significant component of aspen will require a major disturbance to achieve vigorous regeneration. This is most easily and effectively accomplished by clearcutting middle-aged aspen stands.

An increase in the incidence of Armillaria root disease in stands regenerated by clearcutting, is a potential future concern[48]. The *Armillaria* fungus can build up in the stumps and interconnected root systems of harvested trees and affect the new sprouts and suckers. The long-term effects of Armillaria root disease and repeated rotations of aspen, however are still poorly understood.

Major Insects and Pathogens

Forest tent caterpillar (FTC), *Malacosoma disstria*, is a native caterpillar that has recurring regional outbreaks every 7-10 years in the Lake States (photo - Appendix III). FTC has a wide host range, but in the northern Lake States, it is most commonly associated with aspen forests. The caterpillars feed in the spring and early summer on trees of all ages. Outbreaks generally last from 2-3 years in any one location. While most trees survive defoliation, increased levels of stress can lead to increased susceptibility to secondary pathogens and insects. Three years of defoliation can reduce the growth of aspen by 90 percent. A large fly, *Sarcophaga aldrichii*, is commonly associated with the last year of an outbreak. This fly is a native parasite that attacks FTC and aids in the collapse of the population. This so-called "friendly fly" can become a nuisance because of its habit of landing on people. Direct control of FTC has not generally been recommended.

Large aspen tortrix, *Choristoneura conflictana*, is a native defoliator of aspen forests. Outbreaks occur infrequently, but they can cover large areas and may last for 2-3 years. Tree mortality is rarely associated with these outbreaks. The caterpillars feed in early spring.

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[47] Walters, J.W. 1984. A survey of aspen diseases on the Nicolet and Ottawa National Forests. Field Note 84-2. St. Paul, MN: USDA Forest Service, Northeastern Area Forest Pest Management. 14 p.

[48] Stanosz, G.R.; Patton, R.F. 1987. Armillaria root rot in Wisconsin aspen sucker stands. Canadian Journal of Forest Research. 17: 995-1000.

Gypsy moth, *Lymantria dispar*, is an exotic defoliator of aspen as well as many other tree species (photo - Appendix III). No outbreaks of gypsy moth have occurred yet on the Nicolet, though gypsy moth populations have become established in northeastern Wisconsin. Therefore, future outbreaks in aspen stands are likely. Gypsy moth caterpillars are late spring-early summer defoliators capable of stripping leaves from trees over large areas by late June. Outbreaks in Michigan aspen stands have been intense but of short duration, usually lasting only 1 year in any given location. Tree mortality has not been a major problem in these stands to date.

Hypoxylon canker is a serious fungal disease that girdles and kills stems and branches of aspen. The disease is caused by the fungus *Entoleuca mammata* = (*Hypoxylon mammatum*). As much as 12 percent of the aspen growing in the Lake States is affected by this disease. Standing volume loss may run as high as 1 to 2 percent annually. Hypoxylon canker is much more prevalent on "marginal" aspen sites, specifically very wet or dry sites, and in poorly stocked stands. Furthermore, susceptibility varies among aspen clones. This disease causes wood decay and eventually girdles the stem or leads to wind breakage. Management strategies include maintaining high levels of stocking and avoiding very dry and very wet sites. If more than 25 percent of the stand is affected, conversion to another species is recommended. Regenerating susceptible clones will perpetuate the problem.

Armillaria root disease. Fungi in the genus *Armillaria* are a major cause of root disease in aspen. In trees weakened by age or other factors, Armillaria root disease can be the final agent that causes tree death. Armillaria can also affect younger aspen, specifically stands developing from root suckers. An increase in the amount of *Armillaria* inoculum can be expected after thinning or harvest, because it grows in dead and declining root systems. Vigorous stands should be able to survive the increase in *Armillaria* inoculum, but a stand with low vigor may experience a high level of mortality. The most vigorous stands are probably those found on more nutrient-rich, mesic sites.

White trunk rot causes more damage (loss of wood fiber) in pole-size to mature and overmature aspen than any other disease (photo - Appendix III). The fungus responsible is *Phellinus tremulae*. The major determinants of the amount of decay are tree age and clonal susceptability. There does not appear to be any measurable relationship between site and the amount of decay. In general, it can be expected that the older the stand, the more decay will be present in the trees. Some clones are more resistant to decay than others, but it is difficult to identify clone members in a forest. Age and the presence of external indicators (especially conks) are therefore the most important factors in estimating decay and the health of individual trees, although the absence of conks does not mean decay is not present. General guidelines suggest that aspen be managed on shorter, even-aged management rotations to minimize the impacts of white trunk rot. If "old growth" aspen is a desired goal, it should be realized that white trunk rot will eventually cause all of the trees in such stands to fail. Aspen trees older than about 100 years are rare in the Lake States.

Summary

The current age distribution of aspen stands on the Nicolet indicates that most have originated after 1960. On the Nicolet, aspen stands younger than 40 years are generally vigorous and healthy. However, some younger stands were severely affected by drought and defoliation in the late 1980's. Most of these stands are located on the southern end of the Forest. Stands older than 50 are beginning to deteriorate, which is a normal occurrence in Lake States aspen stands. Aspen decay increases rapidly, once trees are more than 50 years old. Outbreaks of defoliators such as forest tent caterpillar and large aspen tortrix will continue to occur. Defoliation will probably be more common when the gypsy moth becomes established locally. In most cases, aspen stands should survive defoliation quite well, though excessive mortality and stand decline can occur if defoliation coincides with periods of drought. Maintaining aspen will require a commitment to intense site disturbance that promotes aspen regeneration. The major health concerns in quaking aspen are:

- Deterioration of older stands - aspen stands rapidly deteriorate past the age of 50 years. This deterioration is generally associated with a rapid increase in the amount of stem decay as aspen ages.

- Defoliation - widespread defoliation is common in aspen stands but it generally does not result in any significant health problems. However, the establishment of gypsy moth in the area could add another significant defoliator.

- Site disturbance - maintaining the aspen cover type requires significant site disturbance to secure regeneration. This can be easily and effectively accomplished by clearcutting middle-aged aspen stands.

- Loss of the aspen type through succession - without active management, the aspen type will be replaced by other tree species on most sites.

Bigtooth Aspen

> *The maintenance of both bigtooth aspen and balsam poplar on the Forest will require an emphasis on disturbance to create conditions suitable for their regeneration.*

Like its cousin quaking aspen, bigtooth aspen is a fast-growing, short-lived pioneer tree species. Bigtooth aspen is capable of growing on a wide variety of sites but is far less adaptable than quaking aspen. It grows best on moist, fertile sandy uplands. It may be found in relatively pure stands, but more commonly it is found in combination with quaking aspen, paper birch, balsam poplar, or northern hardwoods. Bigtooth aspen grows rapidly to age 30 and then begins to quickly slow its growth. Stands reach maturity and begin to decline at 40-45 years on poor sites and at 50-70 years on better sites. Decay fungi, specifically white trunk rot and Armillaria root rot, are the most serious health problem, and are generally associated with overmature stands. However, bigtooth aspen is generally considered much more resistant to aspen diseases than quaking aspen, especially hypoxylon canker. Defoliation by forest tent caterpillar and the leaf roller complexes is quite common. Tree mortality is unusual after defoliations. Bigtooth aspen shows excellent growth characteristics and therefore, it is often favored over other aspen species.

Balsam Poplar

This less common relative of the aspens is also a fast-growing, short-lived, pioneer tree species. The Nicolet is very near the southern edge of this species' range, which largely accounts for its scarcity. Balsam poplar is most commonly found on moist upland or bottomland sites. Its best growth occurs on rich bottomlands. Healthy, vigorous balsam poplar trees require a reliable supply of soil moisture. On the Nicolet, balsam poplar can be found growing in association with quaking aspen, paper birch, and balsam fir on wet sites. On these sites, the quaking aspen and birch are likely to have poor vigor due to the wet conditions.

Balsam poplar has the same pathological problems as quaking aspen.

Defoliation by forest tent caterpillar and aspen leaf beetle can occur but is rather unusual. The highly resinous buds probably discourage many leaf feeding insects. Outbreaks of the large aspen tortrix have been reported in balsam poplar stands.

Paper Birch

Most paper birch trees on the Forest are in the older age classes. Because of this, these trees experience significantly higher mortality rates following drought, major insect outbreak, or other high stress event. Following the 1987-88 drought, many older birch died. It is very likely, due to the present age class distribution, that another wave of mortality will occur after the next stress event. If birch is going to be an important component of the Nicolet in the future, aggressive regeneration techniques will have to be implemented.

Paper birch is a short-lived, pioneer species that is quick to invade sites recently visited by wildfire or other disturbances that remove the canopy and expose mineral soil. On the Nicolet, birch is commonly found in relatively pure stands, in mixtures with aspen, and as a component of northern hardwood stands. Paper birch prefers moist, nutrient-rich soils, though it can occur on dry sites as well as in wet swampy areas. It is common around lakeshores and along roadways and is highly valued for its aesthetic qualities.

Age Class Distribution

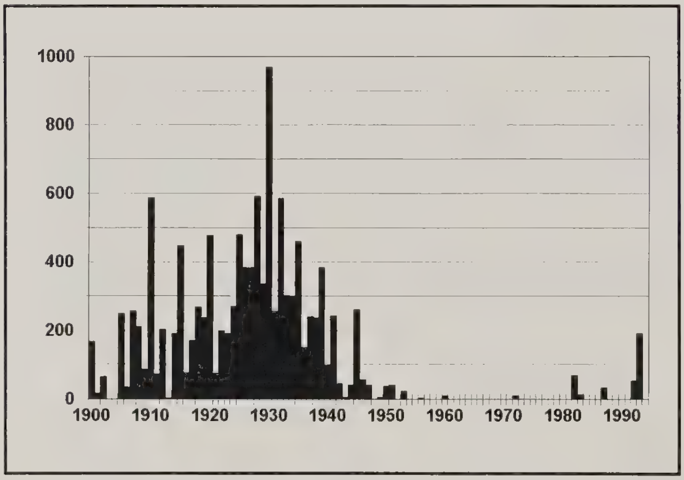

Figure 46. Year of origin of paper birch stands on the Nicolet.

Most paper birch stands on the Nicolet originated during the 1920's and 1930's (Figure 46). Paper birch, being a pioneer species, quickly invaded the many open, disturbed sites available after the abandonment of agriculture and the widespread burning that occurred at that time. Today, that birch resource has aged significantly. At the same time, younger birch stands have not been widely established, resulting in the current age class imbalance.

Historical Disturbance Agents

Paper birch requires disturbance to regenerate. Fires and larger areas of windthrow were two major disturbances that provided opportunities for the initiation of new stands. Paper birch is not a very long-lived tree species, and after 70-80 years it is generally displaced in most stands by more shade tolerant trees. Historically, paper birch probably died in large numbers following a year of intense drought. If a drought year corresponded with an outbreak of a leaf-feeding insect such as the forest tent caterpillar, tree mortality could have been extremely high. Following these periods of drought and defoliation, older, heavily stressed birch trees would have been easily invaded by secondary organisms, such as *Armillaria* spp. and bronze birch borer, which ultimately kill the trees.

Recent Disturbance Agents

Today, drought is probably the most important disturbance agent for paper birch. The impact of drought is compounded because of the relatively old age of birch trees in northeastern Wisconsin. In 1989-92, the upper Great Lakes Region experienced widespread mortality of paper birch after the intense drought of 1987-88 (Figure 47) coupled with widespread birch defoliation by forest tent caterpillar between 1987 and 1991 (see defoliation maps in Appendix II). A 1993 survey conducted in birch stands on the Oneida County Forest in northeast Wisconsin found an average of 15 percent mortality for paper birch[49]. Bronze birch borer and Armillaria root disease were commonly found in dead and dying trees in the early 1990's. In addition to native defoliators such as forest tent caterpillar, paper birch now has several exotic "pests" to contend with — specifically the birch leafminers, which are a group of related insect species introduced from Europe. They feed inside the developing birch leaves, causing additional stress on the birch resource.

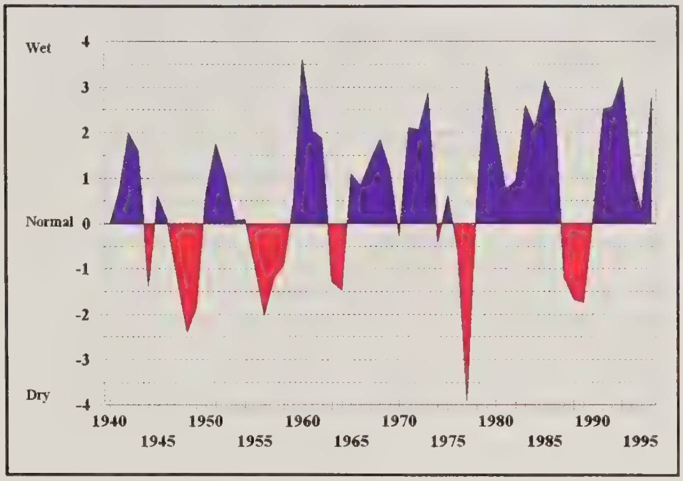

Figure 47. Palmer drought index for northeastern Wisconsin, 1940-1995. The most recent severe drought occurred in 1988, widespread paper birch mortality was reported between 1988 and 1993.

Future Disturbance Agents

In the future, the disturbance agents that affected paper birch historically will be augmented by the addition of the birch leafminers and the eventual establishment of gypsy moth into northeastern Wisconsin. Paper birch is considered a highly preferred food source for gypsy moth caterpillars. These leaf feeders will cause additional stress on birch trees and will likely result in increased attacks by the bronze birch borer and incidence of Armillaria root disease. Young, vigorous birch stands should be able to withstand the various stressors, but many older trees will succumb, especially following periods of drought.

Major Insects and Pathogens

Armillaria root disease, caused by several species of fungi in the genus *Armillaria*, is ubiquitous in North American forests. The fungus grows as a parasite on living tree tissue, most often roots, and on dead woody material in the soil. Armillaria infects and kills trees that are already weakened. In paper birch, weakened trees are a result of old age, drought, and leaf loss caused by insect feeding. Armillaria can continue to kill trees for several years after periods of drought or defoliation.

Bronze birch borer, *Agrilus anxius*, is a native beetle that thrives on weakened birch. The immature stage feeds in winding tunnels under the bark, destroying the ability of a tree to transport food from the leaves to the root system. Healthy, vigorous birch can resist attacks. However, stressed trees are readily invaded and most eventually die, though it may take 3-5 years for an infested tree to be killed.

[49] Department of Natural Resources. 1992. Forest Pest Conditions in Wisconsin. Annual Report 1992. Madison, WI: Department of Natural Resources, Bureau of Forestry. 37 p.

Birch leafminers are now very common "pests" of many birch species in North America. In the Great Lakes Region, there are three species, all of which are exotic to North America. They are *Fenusa pusilla, Profenusa thomsoni*, and *Heterarthrus nemoratus*. *Fenusa pusilla* is generally regarded as the most common and damaging of the three species. It attacks leaves in the early spring and can cause widespread browning of birch foliage by early summer. Leafminer attacks do not kill birch outright, but repeated outbreaks can stress trees, especially older ones. Trees growing along forest edges are more often attacked by leafminers, while interior forest trees are not as severely infested.

Forest tent caterpillar, *Malacosoma disstria*, is a native caterpillar that reaches outbreak levels over the entire Great Lakes Region every 7-15 years (photo - Appendix III). Paper birch is only one of several hardwoods that is fed upon. Defoliation can cause stress, especially if it occurs in conjunction with drought. The most recent outbreak of forest tent caterpillar in northeastern Wisconsin occurred between 1987 and 1991.

Summary

Paper birch is a relatively short-lived tree. Older paper birch trees are very sensitive to drought, especially if it occurs along with defoliation. Drought and defoliation have led to widespread birch mortality during the last 10 years and this is likely to continue as long as most of the birch resource is older than 60-70 years. Exotic insects, specifically birch leafminers and eventually gypsy moth, will act as additional stressors. The following are the most important forest health concerns for paper birch:

- Stand age - stands older than 60 years will have increased levels of tree mortality and these stands will, over a 5- to 20-year period, be eliminated and replaced by more shade tolerant species.

- Regeneration - older birch trees are dying and not being replaced by younger stands. If birch is to remain a significant component of future stands, regeneration efforts will have to be implemented.

- Exotics - gypsy moth and leafminers will cause additional stress in future birch stands.

- Browsing - high deer populations can seriously damage white birch regeneration.

CHAPTER 4

LOOKING FORWARD

This report is meant to provide a record of disturbance agents that have affected the health of tree species on the Nicolet over the past century. It describes the events that shaped the national forest as it exists today. In addition, it provides information that can be used to predict how future management decisions and the disturbance regimes they develop will affect the health of various tree species on the Forest. Not every future disturbance is predictable, but many are, and their possible effects on forest tree species can in many cases be described.

In the discussion that follows we describe a few of the major issues on the Nicolet that will affect the health of tree species in future years. This discussion is not meant to be all inclusive; rather, it is meant to generate further discussion. If we can identify and predict future outcomes using this historical record, then perhaps we can avoid many of our future tree health problems.

Past Land-Use

As discussed in Chapter 1, most of the forest currently found on the Nicolet originated in the early 1900's following a 50 to 70-year period of destructive land-use. This included wide-scale logging, followed in many cases by intense fires, agricultural use, and grazing. These disturbances were intense and significantly altered the area. The legacy of that time period will continue to play an important role in the overall health of the forests of the Nicolet well into the next century, and it is very important that any discussion of future tree health on the Nicolet begin with an understanding of how the current forests originated.

Disturbance Regimes

Disturbance is a part of any healthy functioning forest ecosystem. Historical evidence shows that large areas of the Nicolet were blown down during wind storms and that occasional fires occurred. Undoubtedly, native insects and pathogens often killed single trees or entire stands of trees. These events served to recycle nutrients and provide favorable conditions for trees and plants that demand sunlight. Today, disturbance is just as important as it was previously, though the types of disturbances found on the Forest are different. Fire suppression now limits the size and extent of fires, and harvesting activities alter the species and age distribution of many forest stands. How, where, and when disturbances will be created will play an important role in the future forest composition of the Nicolet.

Forest Management Practices

Future management scenarios on the Nicolet could range from a hands-off policy to one stressing intensive forest management. Whatever scenario is stressed will affect the health of trees in some way. A hands-off policy that discourages human-caused disturbances will also discourage certain tree species such as aspen, paper birch, oak, and jack pine. On the other hand, it could encourage species such as sugar maple and American beech. The past history of disturbances, human-made and "natural," including insects and pathogen outbreaks, should provide a basis for predicting what is likely to happen to various tree species under different management scenarios.

Many management practices can directly affect the health or vigor of individual trees. A healthy, vigorous tree can better defend itself from insect or pathogen attack than can a weakened or stressed tree. Practices such as thinning can develop larger, healthier tree crowns that can increase tree vigor. In some cases, such as in oak stands, thinning to increase tree vigor may become very important in the maintenance of oak as a dominant species due to the presence of gypsy moth, an exotic leaf feeder of oaks.

Finally, basing future forest management decisions on sound ecological principles could alleviate several of our major tree health concerns. The advent of ecological classification systems is a major step toward that goal. These systems provide the basis for managing tree species on ecologically appropriate sites, thus avoiding past mistakes that placed some tree species on sites that were too wet or too dry, too nutrient poor or too nutrient rich. These mistakes often led to tree health problems. Further, the ecological classification systems provide a very good predictive tool that can be used to illustrate what a stand or forest will look like following any management practice. Various ecological classification systems are now available for use on the Nicolet, including the "Field Guide to Forest Habitat Types of Northern Wisconsin."

Deer Populations

The role deer play in the ecology of the Nicolet forest could be significant, especially in localized areas such as winter deeryards. High deer populations are often blamed for eating young northern white-cedar, yellow birch, white pine, and hemlock, all species that are highly desired for their contribution to biodiversity, wildlife, and timber. Future deer management could affect the regeneration of these trees as well as other plants on the Forest.

Introduction of Exotic Organisms

Perhaps the greatest threat to the future health of the tree species of northeast Wisconsin is from the introduction and establishment of exotic insects and pathogens. Past history includes well-documented cases where the introduction of an exotic organism disrupted forest ecosystems. The introduction of chestnut blight forever altered the forest ecosystems of the Eastern U.S. In Wisconsin, Dutch elm disease killed literally thousands of American elm. Though often thought of only as a tree of city streets, American elm was also a dominant tree in many forests, especially on wetter sites. Today, large American elm are rare in Wisconsin forests, and the lowland hardwood forest, which is well represented on the Nicolet, has been significantly altered by the loss of this once dominant tree. At present, more than 360 exotic insects and more than 20 exotic pathogens are known to attack woody plants in North America.[50] A number of these are already well established on the Nicolet (Table 2).

Today, exotic introductions continue to threaten the Nicolet. Gypsy moth, a major forest defoliator, has become established in northeastern Wisconsin. Gypsy moth outbreaks are common in forests dominated by oak and aspen. Gypsy moth caterpillars also feed readily on basswood, tamarack, and willow and can feed upon white pine and hemlock. Gypsy moth feeding can have profound effects in some forests and it will alter the ecology of the Nicolet, especially in areas dominated by oaks. Several exotic insects, and pathogens that could eventually become a problem on the Nicolet are already present in the U.S. (Table 3.) Others will be accidentally introduced in the future. Any of these could have a severe impact on the Nicolet.

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[50] Haack, R.; Byler, J. 1993. Insects and pathogens: Regulators of forest ecosystems. Journal of Forestry. 91: 32-37.

Table 2. Some of the major exotic insects and pathogens currently established on the Nicolet National Forest.

Diseases and Pathogens	Place of Origin
Dutch elm disease, *Ceratocystis ulmi*	Europe
White pine blister rust, *Cronartium ribicola*	Europe
Butternut canker, *Sirococcus clavigignenti-juglandacearum*	Unknown
Insects	
Larch sawfly, *Pristophora erichsonii*	Eurasia
Larch casebearer, *Coleophora laricella*	Europe
Gypsy moth, *Lymantria dispar*	Europe
Introduced basswood thrips, *Thrips calcaratus*	Europe
Introduced pine sawfly, *Diprion similis*	Europe
Smaller European elm bark beetle, *Scolytus multistriatus*	Europe
Birch leafminers, *Fenusa pusilla* and *Profenusa thomsoni*	Europe
Elm leafminer, *Fenusa ulmi*	Europe
Maple petiole borer, *Caulocampus acericaulis*	Unknown

Table 3. Future threats to the Nicolet National Forest from exotic insects and pathogens already established in parts of the United States.

Diseases and Pathogens	Current Status
Beech bark disease, *Nectria coccinea* var. *faginata*	In northeast Ohio, infects beech
Scleroderris canker (European strain), *Gremmeniella abietina*	In New York, infects red pine
Insects	
Hemlock woolly adelgid, *Adelges tsugae*	Present in the Eastern U.S., infests hemlock
Larger pine shoot beetle, *Tomicus piniperda*	Present in southern Wisconsin, infests several native pines
Pear thrips, *Taeniothrips inconsequens*	Present in Wisconsin, infests sugar maple

Other exotic organisms also threaten the Nicolet. These include a number of plants such as purple loosestrife, spotted knapweed and European buckthorn.

Air Pollution

Air pollution in the form of ozone or acidic rain can have a widespread detrimental effect on many tree species. At this time, no apparent air pollution problem exists on the Forest. Nevertheless, it is a potential future concern that should be monitored.

Summary

Past and future practices will have significant effects on the health of the various tree species on the Nicolet. The forests of the region have made a significant recovery from the abuse that occurred during the logging era of the middle to late 1800's and the brief agricultural era that followed. Nevertheless, the effects of those past events are still present and will be for many more years. Other events have occurred, such as the introduction of Dutch elm disease and white pine blister rust, that also will affect tree health well into the future. Gypsy moth has become established on the Nicolet and it too will have an impact in many forest stands. Future introductions of exotics that threaten other tree species are very possible. Finally, decisions on how forest management will be practiced on the Nicolet will directly affect tree health. Whatever the management decisions are, the use of ecological classification systems should provide a basis for making better decisions in managing many forest stands.

APPENDIX I

MONITORING TREE HEALTH IN NORTHEASTERN WISCONSIN

The Forest Service has been actively monitoring insect and disease activity on the Nicolet since 1962, when an insect and disease specialist was first based on the Forest. In 1966, the insect and disease staff was relocated to form a new unit at a field office in St. Paul, Minnesota. In addition, Wisconsin's trees and forests have been monitored for insect and disease outbreaks since 1953 and reported on by the Forest Pest Management unit of the State's Department of Natural Resources. Information collected by these two groups provides a long-term record of insect and disease activity in northeastern Wisconsin. It also documents periods of tree decline or mortality that have often been associated with weather events such as droughts and windstorms.

What is the Forest Health Monitoring Program?

To better monitor tree and forest health, the Forest Service along with its state cooperators initiated the Forest Health Monitoring (FHM) Program in the early 1990's. The program was developed for monitoring and reporting on the status and trends of forest ecosystem health. The USDA Forest Service and State Forestry and Agriculture agencies conduct FHM activities in cooperation with several other program participants. In Wisconsin, the Department of Natural Resources has been an active participant along with the Forest Service since 1994.

The FHM program is comprised of three interrelated monitoring activities: detection monitoring; evaluation monitoring; and intensive site ecosystem monitoring. A related activity is research on monitoring techniques.

What is detection monitoring?

Detection monitoring is the most extensive of FHM's three monitoring activities. It is designed to provide information to determine baseline or current conditions of forest ecosystems, and to detect changes and trends over time. This information is analyzed to determine if detected changes indicate improving forest health or are cause for concern, warranting additional evaluation. Detection monitoring covers all forested lands and has two components that together describe forest health: (1) the plot component—measurements made on the FHM network of permanent plots (Figure 48); and (2) the survey component—surveys of insects, diseases, and other stressors. The surveys are conducted independently of the plot network.

Figure 48. Location of forest health monitoring plots in Wisconsin and Michigan's Upper Peninsula.

What is measured as part of the plot component?

FHM uses measurements or groups of measurements called indicators. An indicator is defined as any biological or non-biological component of the environment that quantitatively estimates the condition or change in condition of ecological resources, the magnitude of stress, or the exposure of a biological component to stress. The current set of indicators being measured in detection monitoring includes lichen communities, ozone bioindicator plants, tree damage, tree mortality, vegetation structure, plant diversity, tree crown condition, tree growth, and tree regeneration.

The FHM design allows national and regional assessments to be made from detection monitoring data. Intensified sampling can be used to answer more localized questions. Although the Nicolet itself has only six FHM plots, neighboring plots can be used to detect changes in forest health (Figure 48).

What is measured as part of the survey component?

The symptoms of natural and human-caused stressors that affect forests are detected and measured with aerial and ground surveys. Important stressors are insects, diseases, climate changes, extreme weather, and air pollution. Commonly measured symptoms include defoliation, foliage discoloration, tree dieback, branch breakage, main stem breakage, and tree mortality. On the Nicolet, Chequamegon and Ottawa National Forests, insect and disease surveys are conducted by the Forest Service insect and disease unit. On adjacent lands, surveys are conducted by the Wisconsin or Michigan Department of Natural Resources. This information is combined to provide a regional picture of forest insect and disease activity over large areas. Climate, weather, and air pollution data are obtained from other agencies.

How will the data be used?

Detection monitoring data are used in making national and regional assessments of forest condition. Both the national and regional annual data reports present data from the previous field season. The goal is to integrate plot and survey data so that a more complete picture of forest conditions is possible. This kind of assessment requires fitting different indicators together so they present an ecosystem-level picture as well as a look at individual parts of the ecosystem.

Are there other monitoring programs?

During the late 1970's and throughout the 1980's, sugarbush managers and foresters who managed northern hardwood stands became concerned about maple decline. A special project was designed to monitor and evaluate sugar maple condition, particularly in relation to pollution and stand management intensity. The North American Sugar Maple Decline Project was formed in 1987 by Canada and the United States to determine:

- The rate of change in sugar maple tree condition ratings.
- If the rate of change in sugar maple tree condition ratings are different among:
    - various levels of sulfate and nitrate wet deposition
    - sugarbush and undisturbed forest
    - various levels of initial stand decline conditions
- The possible causes of sugar maple decline and the geographical relationships between potential causes and extent of decline.

Observations are made annually on about 18,500 trees, of which approximately 70 percent or 13,421 are sugar maples. Wisconsin and Michigan are active participants in this project. This data is relevant to the Nicolet since sugar maple is a dominant tree on the Forest. The other common species surveyed are American beech, yellow birch, red maple, and ash. Sugar maple crowns are evaluated for dieback, foliage transparency, discoloration, and insect defoliation. The incidence of these stress indicators fluctuates from year to year, probably as a result of individual tree response to changes in weather and site conditions. Continued monitoring will reveal long-term trends in forest health and possibly disclose the impact of disturbances such as global warming, air pollution, defoliation, drought, or a combination of these.

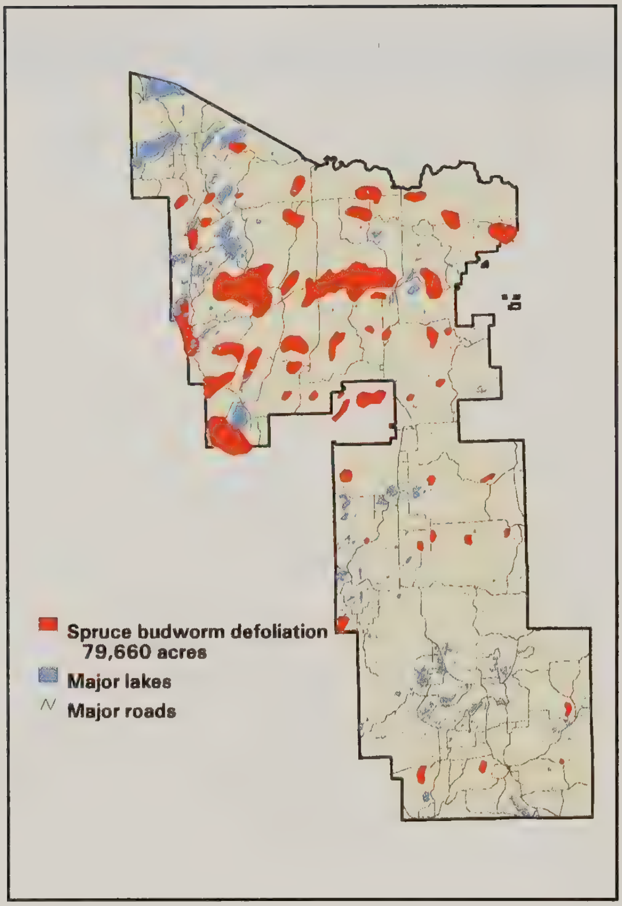
Forest Inventory and Analysis Program (FIA) of the Forest Service also provides a great deal of information relevant to health-related issues although FIA is not designed specifically to monitor tree or forest health. Its objective is to periodically inventory the Nation's forest land to determine its extent, condition, and volume of timber growth and removals. Wisconsin's first FIA inventory was in 1936 and its most recent inventory was completed in 1996. In addition to these programs, a number of relevant research studies and reports have been generated by Forest Service Research units and by faculty and graduate students within the University of Wisconsin system.

APPENDIX II

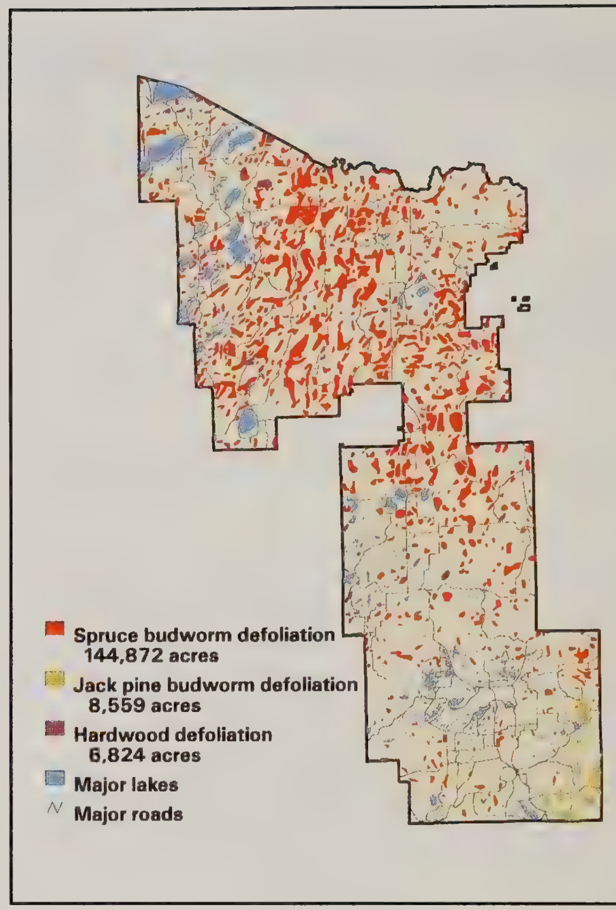
ANNUAL AERIAL SURVEY MAPS

Maps and records of aerial surveys conducted by the Forest Service date back to the 1950's. The earliest record of an aerial survey of the Nicolet National Forest is from 1975. Throughout the 1970's and 1980's, most aerial pest surveys were done to respond to requests from Forest personnel to assess pest conditions before or after pest control programs, or to locate dead and dying stands for salvage operations. Because of this, aerial surveys were not conducted on a routine basis. However, since the late 1980's, the aerial survey programs have been driven by a growing public concern for general forest health and ecosystem conditions and by a growing appreciation for the value of a complete historic record of major pest events. Therefore, annual aerial surveys are now conducted.

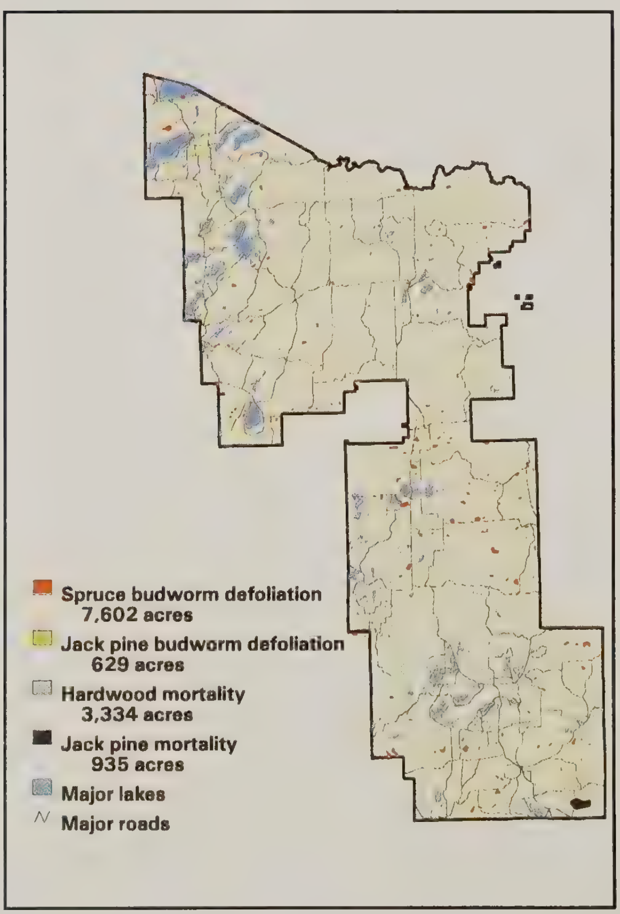
Currently, annual aerial sketchmap surveys of all Lake States national forests, including the Nicolet, are typically done in late June or early July. Sketchmapping surveys are conducted using small, single engine, high-wing aircraft and a crew of two sketchmappers in addition to the pilot. A series of parallel flight lines are flown across the area of interest at 3- to 4-mile intervals. Visible defoliation or other evidence of pest activity is sketched onto maps. Affected areas are subsequently ground checked to determine or confirm the causal agent. The results of the sketchmap surveys are then computer digitized and combined with data from similar surveys conducted by State personnel to produce statewide data for State reports and for the National Forest Health Monitoring Program. Aerial sketchmapping by trained observers is an accurate and relatively inexpensive method of obtaining acreage and severity estimates of disturbance events that would otherwise be nearly impossible to obtain.



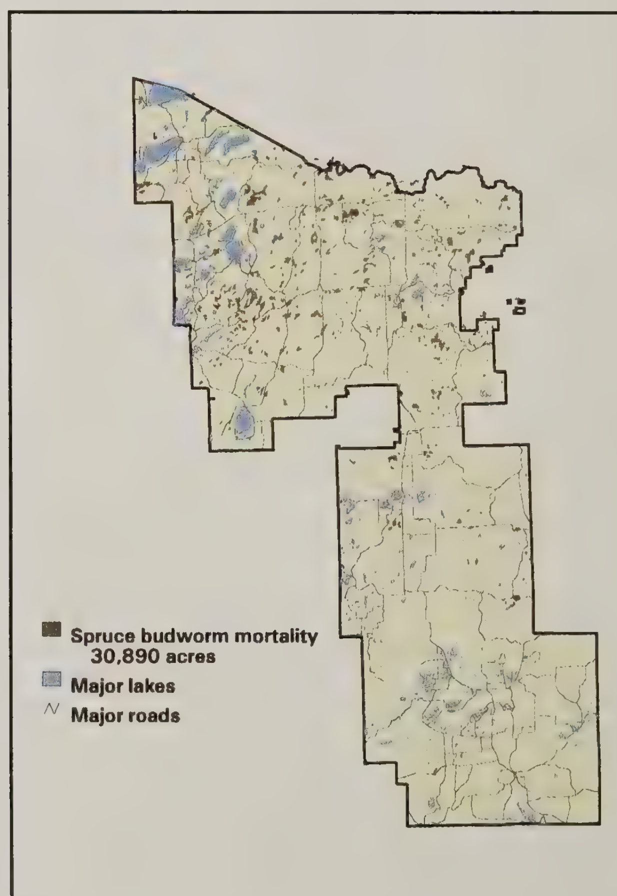
1975 Aerial Detection Survey



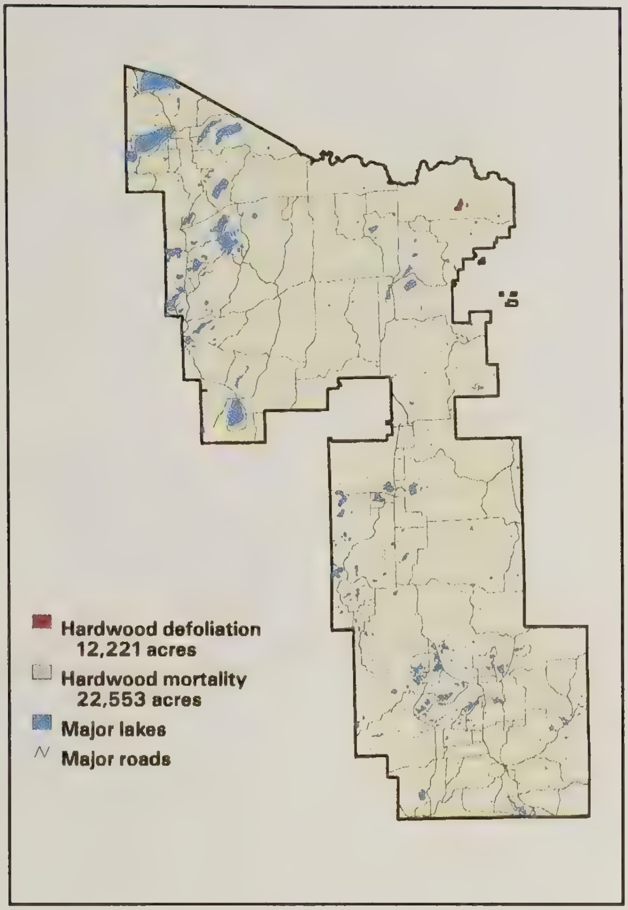
1980 Aerial Detection Survey



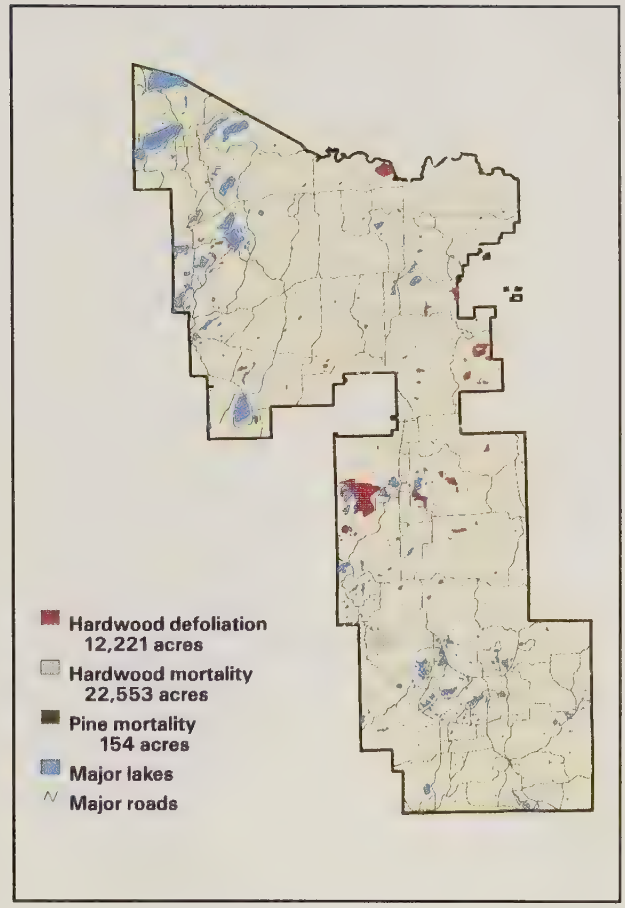
1981 Aerial Detection Survey



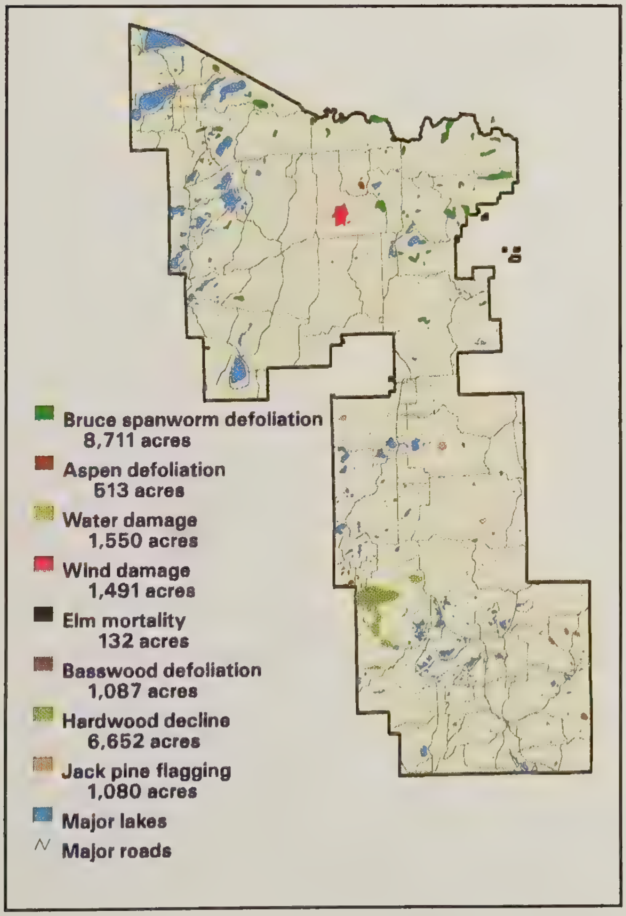
1982 Aerial Detection Survey



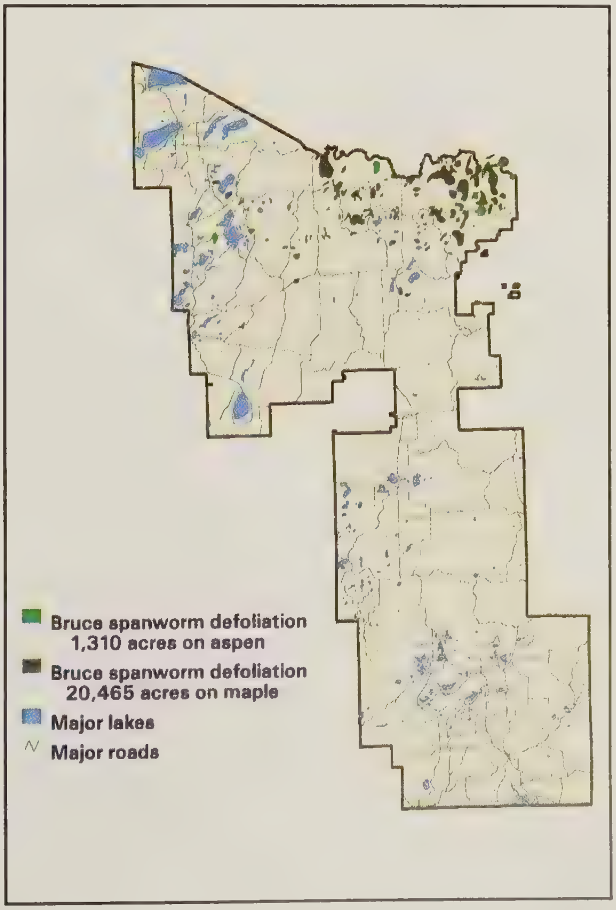
1983 Aerial Detection Survey



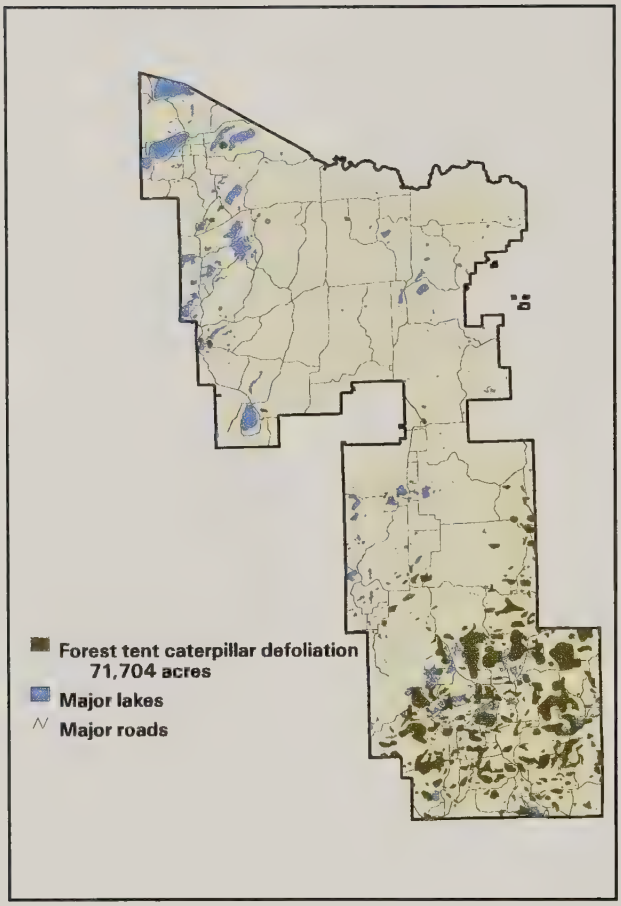
1984 Aerial Detection Survey



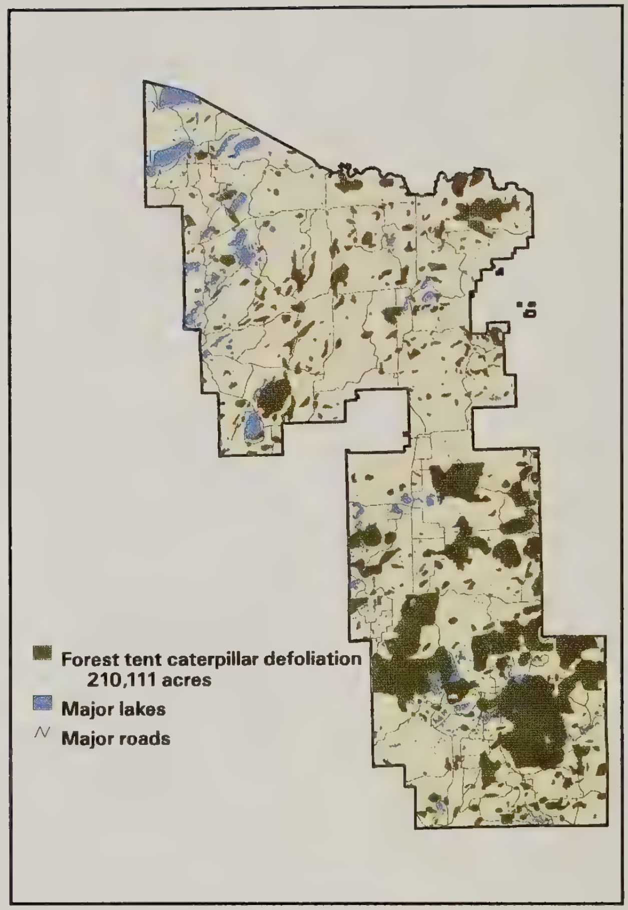
1985 Aerial Detection Survey



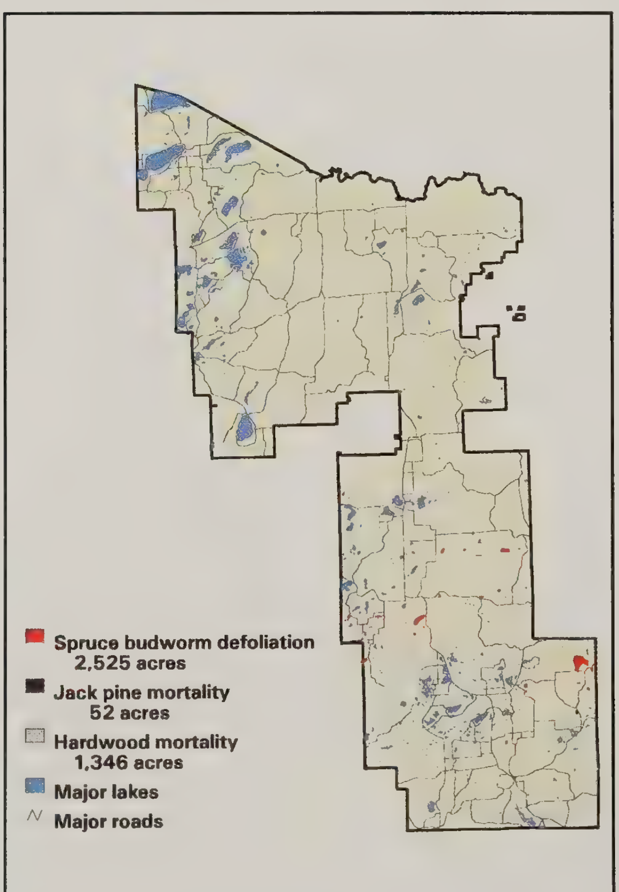
1986 Aerial Detection Survey



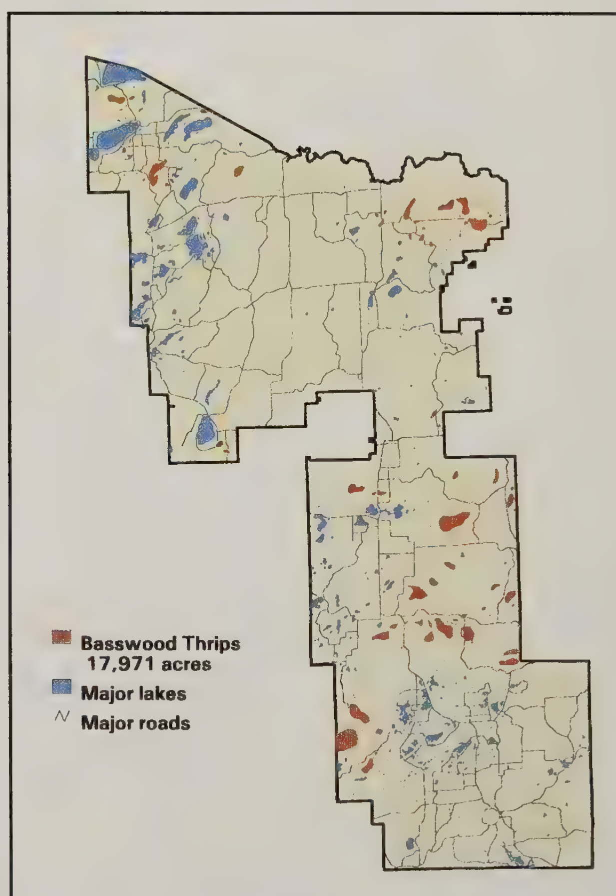
1989 Aerial Detection Survey



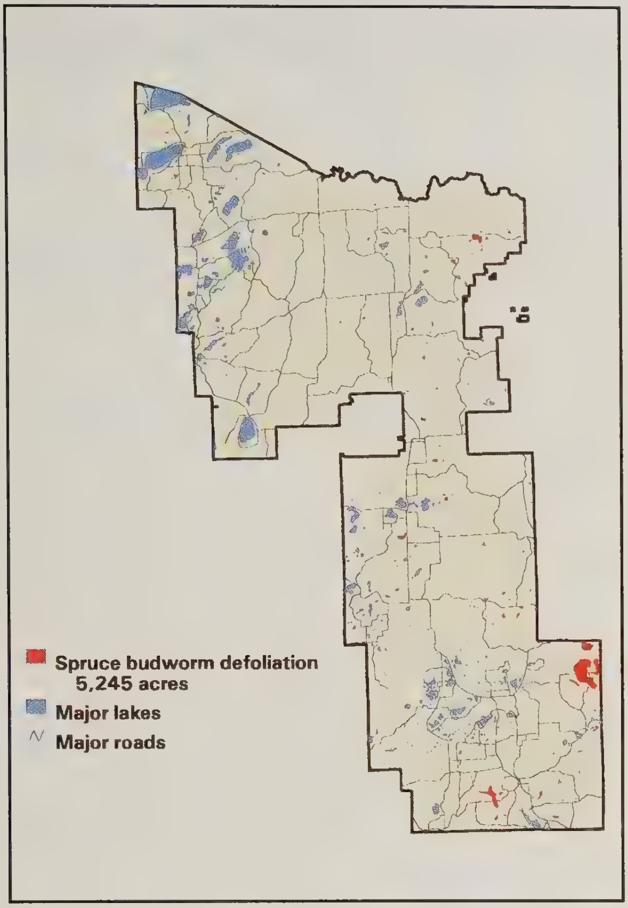
1990 Aerial Detection Survey



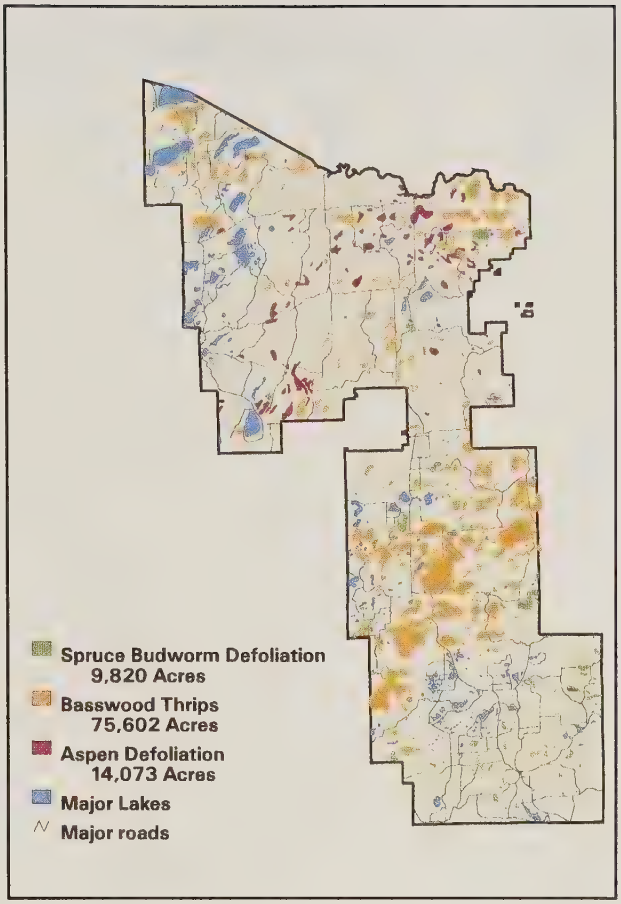
1995 Aerial Detection Survey



1996 Aerial Detection Survey



1997 Aerial Detection Survey



1998 Aerial Detection Survey

APPENDIX III

PICTURES OF MAJOR PESTS

Insects
Forest tent caterpillar
Gypsy moth
Introduced basswood thrips
Jack pine budworm
Larch sawfly
Spruce budworm
Sugar maple borer
White pine weevil

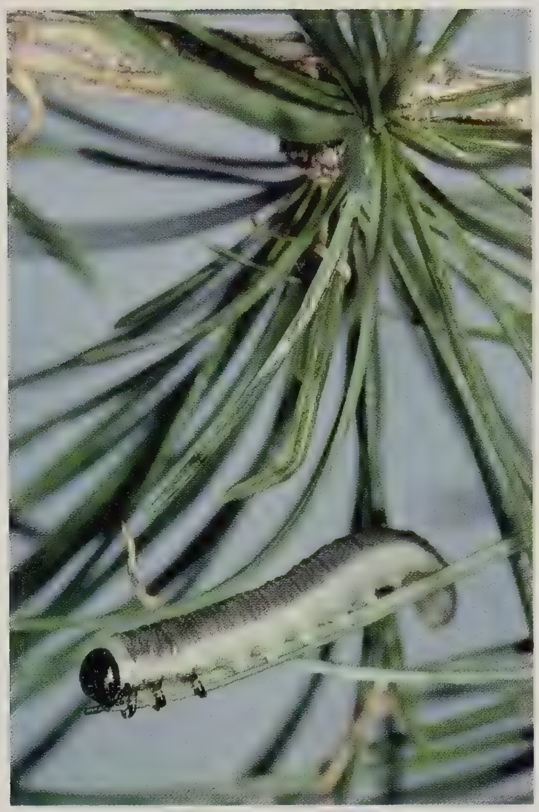
Diseases
Butternut canker
Eutypella canker
Red pine shoot blight
White pine blister rust
White trunk rot of aspen

Forest tent caterpillars.

Gypsy moth caterpillar.

Early spring defoliation on basswood caused by introduced basswood thrips feeding.

Browning of needles on jack pine caused by needle feeding by the jack pine budworm.



Larvae of the larch sawfly feeding on tamarack needles.

Spruce budworm caterpillar.

Sugar maple borer damage on the stem of a sugar maple tree.

White pine weevil attacks that kill terminals in young white pine can result in stem deformity in later years.

A dead "cankered" area on a butternut stem caused by butternut canker.

Young red pine infected with red pine shoot blight.

White pine stem with a white pine blister rust infection.

Eutypella canker on sugar maple. This canker often forms a characteristic cobra head.

Conks on aspen caused by the fungus responsible for white trunk rot.